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THE 1967 DEER SEASON IN THE MOOSE RIVER RECREATION AREA[1]

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ABSTRACT

The vicinity of "The Plains" along the South Branch of the Moose River has been a deer study area since 1931. Recent emphasis has been on developing more effective harvest techniques which will have application to this area and in other localities throughout the State.

Following a major land acquisition by the State, the 80,000-acre Moose River Recreation Area was established and opened to public hunting in 1964. Despite the hunting done during the first three years, including hunting under special antlerless deer licenses in 1966, the Area had an overpopulation of deer in 1967. Accordingly, a larger number of special licenses was issued that fall in an effort to reduce the population to its 1966-67 level. Information concerning both the hunters and the deer taken was obtained at checking stations operated at the two entrance points. Of 6,457 hunters, 3,293 were special license holders. Hunting pressure was highest during the first week of the season, but it dropped sharply after that. The take of 497 deer followed substantially the same pattern, but hunting success in terms of effort expended was best during the last nine days of the season. Most of the hunting was done within a mile of a road, and 97 per cent of the total harvest came from about 60 per cent of the Area. Data on age composition indicated that winter losses among fawns were heaviest in 1966-67 and that among the adults the harvests by hunting and all other losses combined were not enough to prevent substantial numbers from attaining the ages at which many die of old age during the winter. Despite the fact that hunting on the Area in 1967 was considered good, it is felt that more deer should have been removed and that substantially more male deer and considerably more female deer should be harvested in the future.

The area in the vicinity of "The Plains" along the South Branch of the Moose River in central Hamilton County has been the scene of intensive deer studies by the Division of Fish and Game since 1931. The early work there helped provide an understanding of the problems confronting deer management in the central Adirondacks. Following acquisition of a key tract by the State, the Moose River Recreation Area was established and opened to the general public in 1964. This provided the opportunity to achieve more adequate deer harvests. Also, since the Conservation Department obtained control over the road network on the Area, a unique opportunity was pro-

[1] The Department is sincerely grateful to the sportsmen who have cooperated so well in this venture. We hope that they have enjoyed taking part in the development of better deer management techniques.

vided for accurately measuring hunting effort and obtaining deer harvest information. Emphasis has been placed on finding means to take the fullest advantage of the harvest potential of the deer population on the Area and at the same time provide the greatest amount of recreational opportunity to the sportsmen who come there. The results may have application not only elswhere in the central Adirondacks but in other localities throughout the State.

BACKGROUND

A brief history of the area and its deer population will provide a background for the data obtained during the 1967 hunting season. A more comprehensive account was given by Smith and Severinghaus (1954).

History of the Area

Throughout recent history the deer population in the drainage of the South Branch of the Moose River and its headwaters tributaries has been the subject of considerable discussion and study. The initial logging operations that were conducted in portions of the area had resulted in an abundance of browse, and available records indicate that deer flourished there during the early 1880's. However, without adequate population control the deer soon became too abundant for the available browse. This overpopulation, coupled with the continued reduction of essential evergreen shelter by cutting, produced critical conditions. "The Plains" and vicinity became a major deer wintering area. The lowland softwood and mixed growth attracted large numbers of deer when deep snow impeded travel and when temperature and wind conditions created a need for shelter. Winter mortality was reported in 1889. During the 1890's and early 1900's various observers reported winter deer starvation, with heavy losses in some years. After that, such losses recurred when winter conditions were severe. But through the years, the quantity, quality and interspersion of food and shelter there has determined the number of deer that the entire drainage would support.

In the 1940's, blowdown of overmature trees began to create small openings in the forest. Then came hurricane Hazel in November of 1950. Large areas of mature and overmature spruce and balsam were subjected to very heavy blowdown. Salvage operations were subsequently conducted on State lands beginning about 1952, and on private lands these salvage jobs were coupled with hardwood and softwood logging operations. The opening or removal of the forest canopy over much of this area stimulated the growth of an abundance of new browse as well as coniferous shelter. These changes com-

bined to produce a unique situation in which there was an abundance of food and shelter in relation to the number of deer present. The deer population reacted positively to these favorable conditions by an irruptive increase, beginning about 1959, and soon caught up with the higher carrying capacity of the range. By 1964, the high quality foods in the wintering area were being completely browsed, the less preferred species were heavily browsed and moderate browsing was noted on starvation species such as white pine, balsam and larch. Winter food supplies were being depleted more rapidly than new growth could replace them.

In December 1963 a tract of 53,378 acres adjoining "The Plains" was acquired by the State from the Gould Paper Company. This not only opened lands that had been posted, but it also provided access to State lands that had been previously inaccessible to the public. From this tract and other contiguous State land the Moose River Recreation Area of some 80,000 acres was established and opened to the public in 1964. The main road through the Area provides the only means of entrance by car: from the west from Limekiln Lake near Inlet; from the east from the foot of the Cedar River Flow south of Indian Lake Village. At each entrance the Division of Lands and Forests maintains a gate where persons entering the Area must register. Another gate is maintained on the Area near the mouth of Otter Brook beyond which only four-wheel-drive vehicles were permitted. Camping is permitted in designated areas along the roads and elsewhere by permission.

THE SITUATION IN 1967

Following establishment of the Area and opening of the roads to the public, each hunting season produced a higher deer harvest than the previous one due to a number of factors. Improvement and expansion of the road network from year to year facilitated greater access and better distribution of hunters throughout the Area. In 1964 and 1965 deer were hunted pursuant to a big game license or deer hunting party permit only. In 1966 special antlerless deer licenses were also issued for most of the Area. This license entitled the holder to take one antlerless deer (deer without antlers or with antlers less than 3 inches long) in addition to what he might take under his big game license or party permit. The objectives were to provide greater deer hunting opportunity and to promote a more adequate harvest.

Nevertheless, in the spring and summer of 1967 a relatively high deer population existed as a result of low harvests and four consecutive mild winters. The mild weather enabled the deer to use a much larger proportion of the range during the winter, and survival

of fawns was exceptionally good. Analysis of data concerning the deer population and hunting pressure during the previous three seasons, supplemented by annual field surveys during the winter and spring, led to the following conclusions:

1. The degree of harvest had not been sufficient to keep the deer population in balance with the available winter food supply.
2. For adult males, the average antler beam diameter and the average number of antler points indicated that the deer were not obtaining adequate food. This was especially noticeable in the case of the yearlings where a very significant percentage were not producing antlers of legal size[2].
3. Weight records also indicated that the deer were not obtaining adequate food.
4. In the deer wintering area virtually all of the available nutritious browse had been consumed during the winter of 1966-67.
5. The available browse would not support a deer population larger than that which was present during the winter of 1966-67 without serious destruction to the growing stems of the existing plants and consequent deterioration of future carrying capacity.
6. Heavy starvation losses could have occurred had the winter of 1966-67 been severe.
7. Hunting pressure was adequate only during the early part of each season. Improved hunter distribution throughout the Area and increased hunting pressure after the first week were needed.
8. A larger number of hunters could be afforded the opportunity of taking antlerless deer.
9. Deer hunting regulations for the 1967 season should be designed to produce a larger harvest of antlerless deer so that the wintering population in 1967-68 would be no larger than that in 1966-67.

THE 1967 DEER SEASON

Regulations for hunting pursuant to the special antlerless deer license are fixed by Department order, and those for 1967 were similar to those for 1966. The major change was that the quota of licenses to be issued was increased from 1,600 to 7,000. This decision was

[2] To be taken legally under a big game license, a deer must have antlers at least 3 inches long.

based on the lower-than-anticipated success rate of hunters in 1966 and the concentration of hunting pressure during the first week of the season. Successful applicants were to be selected on a random rather than a first come-first served basis, but this became unnecessary because the quota was under-subscribed. The fee for the license was lowered from $2.00 to $1.00. As before, possession of a big game license was prerequisite to applying for a special antlerless deer license; but party permits for Area B were also valid on the Area, and hunters could hunt bucks with only a big game license if they wished. Therefore, it was possible for a hunter legally to take three deer from the Area if he possessed all the necessary licenses.

When he entered the Area to hunt, the holder of a special antlerless deer license was required to obtain a self-locking metal seal. The seal had to be affixed to any deer taken under that license or, if no deer was taken, surrendered when he left the Area. If he re-entered the Area, a hunter who had not filled his license could obtain a new seal.

COLLECTION OF DATA

All hunters, regardless of whether or not they held a special license, were required to bring out any deer taken by way of one of the two road entry points and have it examined. At each a checking station was operated throughout the deer hunting season, and personnel of the Bureau of Game stationed there collected data on the hunters and the deer they took. The following types of information were gathered.

HUNTER QUESTIONNAIRES As many hunters as possible were given questionnaires which they were asked to fill out prior to leaving the Area. The requested information included the date and time they entered the Area, the date and time they left, the licenses and permits under which they hunted, the area they hunted (open to all vehicles, open to four-wheel-drive vehicles only or both areas) and the total number of live deer they saw while hunting.

HUNTING PRESSURE At the checking stations, the license number of each holder of a special license was recorded each time he entered or left the Area, and the number of each seal issued him was recorded together with the date it was issued and the date it was returned or brought out on a deer. These data afforded a means of determining the number of such hunters on the Area from day to day and the man-days of hunting effort. The number of hunters present who did not possess special antlerless deer licenses was calculated from the information obtained from the questionnaires.

Deer Taken Deer taken were examined at the checking stations, and for each the following data were recorded: sex, age as determined from tooth replacement and wear, date and location of kill, date checked and license type and number. To facilitate recording the kill location, grided topographic maps were prepared so that each unit represented a quarter square mile. Hunters were questioned fully to obtain accurate locations. At least half the deer were weighed. In the case of adult males, the number of antler points and antler beam diameters were also recorded.

Bears Taken Bears taken were also examined at the checking stations. For each, the sex and the location of kill were recorded as well as the big game license number of the hunter.

Findings

The data obtained relate to a number of considerations that are of interest in evaluating the 1967 deer season in the Moose River Area. These are discussed separately.

Use of Special Antlerless Deer Licenses Four possible license and permit combinations existed. The records showed that 46 per cent of the hunters held a special antlerless deer license and the prerequisite big game license, 46 per cent held only a big game license, 3 per cent held a big game license and an Area B party permit, and 5 per cent held both licenses and a permit.

Of the 7,000 special antlerless deer licenses that were available, only 5,428 were applied for and issued. A number of persons who hunted under their big game license stated that they did not know the special license was available. Of the 5,428 licensees, only 3,293 (61 per cent) ever came to the Area and obtained metal seals. This compared with a 75 per cent turnout during the 1966 season.

Most of the 3,293 special license holders who actually hunted on the Area hunted during the first period (October 25-29). Some hunted during more than one period. The number and percentage present during each period are shown in Table 1. The number of different periods of the season during which individual special license holders hunted is summarized in Table 2. The great majority hunted only during one period, while only three hunted in all six periods. The records further revealed that 54 per cent hunted during the first period only, while 23 per cent hunted during more than one period.

The deer hunting season on the Area was concurrent with that throughout the Northern Zone, i.e., October 25 to December 5. For the purpose of tabulating the data on license use it was divided into six periods. In general, the periods ran from Monday morning through

TABLE 1. NUMBER AND PERCENTAGE OF SPECIAL ANTLERLESS DEER LICENSE HOLDERS PRESENT ON THE MOOSE RIVER AREA DURING DIFFERENT PERIODS OF THE SEASON IN 1967

Period	Number	Per cent*
October 25–October 29	2,406	73
October 30–November 5	735	22
November 6–November 12	577	18
November 13–November 19	241	7
November 20–November 26	192	6
November 27–December 5	198	6

* Of the 3,293 who actually hunted on the Area at some time during the season.

TABLE 2. DISTRIBUTION OF SPECIAL ANTLERLESS DEER LICENSE HOLDERS ON THE MOOSE RIVER AREA ACCORDING TO NUMBER OF PERIODS DURING WHICH THEY HUNTED IN THE SEASON OF 1967

Number of periods	Hunters	
	Number	Per cent
1	2,534	76.9
2	551	16.7
3	140	4.3
4	50	1.5
5	15	0.5
6	3	0.1
Total	3,293	100.0

Sunday night except for the first and last periods. The first period extended from the opening day, which was a Wednesday, through the following Sunday; while the last period extended from Monday through Sunday and also included the last two days of the season.

HUNTING PRESSURE A fairly accurate picture of the hunting pressure during the different periods of the season was derived from the records on the use of the metal seals and from the information on the questionnaires that were returned. The data are summarized in Table 3. The total for hunters present exceeded the actual number of license holders because of the number of individuals who hunted during more than one period. Of this total, 55 per cent hunted during the first period, after which the proportion dropped off sharply, and only 5 per cent hunted during the last period. Information from the questionnaires indicated that 51 per cent of the hunters possessed a special antlerless deer license. Since 3,293 special license holders were known to have hunted on the Area, it was calculated that the total number of individual hunters was 6,457. Considering the total

TABLE 3. HUNTING PRESSURE ON THE MOOSE RIVER AREA DURING DIFFERENT PERIODS OF THE SEASON IN 1967

Period	Hunters present				Man days	
	Special license holders	Other big game hunters*	Total		Average per hunter§	Total
			Number	Per cent		
October 25–October 29	2,406	2,312	4,718	55	1.9	8,964
October 30–November 5.	735	706	1,441	17	1.5	2,162
November 6–November 12.	577	554	1,131	13	1.6	1,810
November 13–November 19.	241	231	472	6	1.3	614
November 20–November 26.	192	184	376	4	1.4	526
November 27–December 5.	198	190	388	5	1.2	466
Total	4,349	4,177	8,526	100	1.7	14,542

* Derived from data for special license holders; questionnaires indicated that 51 per cent of the hunters held special antlerless deer licenses.
§ Calculated from information furnished on the questionnaires.

value of 8,526 for hunters present, it follows that there were 1.3 visits per hunter.

Not only did the number of hunters present drop after the first period, but they tended to spend less time (average man days) on the Area as the season progressed. However, the figures for man days included travel time, time spent setting up camp, etc, in addition to the time actually devoted to hunting. Those hunting in the section open only to four-wheel-drive vehicles (area south of Otter Brook check point) tended to stay longer than those hunting in the portion open to all vehicles. Hunters in the four-wheel-drive section stayed an average of 2.1 man days.

A relatively high percentage of the hunters remained in the Area for only one-half day or less during a visit. For the purpose of standardization, a hunter who entered the Area after 9:30 a.m. or who left before 2:30 p.m. was given credit for one-half man day on that particular day. The data (Table 4) represent only hunters who returned the questionnaire. Of these, an average of 19 per cent remained one-half day or less, and during the fourth period of the season the proportion was 35 per cent. However, the log book at the Cedar River checking station showed that for the entire season 46 per cent of those who visited the Area for only one day actually stayed one-half day or less. Obviously the group represented by the questionnaire included campers who naturally would tend to stay for more than half a day.

Since this was the first year that a detailed study had been made of the hunting pressure in the Moose River Recreation Area, it is

TABLE 4. DEGREE TO WHICH HUNTERS REMAINED IN THE MOOSE RIVER AREA ONLY ONE-HALF DAY OR LESS IN 1967

Period	Total hunters*	Hunters remaining ½ day or less§	
		Number	Per cent
October 25–October 29	3,642	555	15
October 30–November 5	963	257	27
November 6–November 12	874	174	20
November 13–November 19	367	127	35
November 20–November 26	329	75	23
November 27–December 5	242	56	23
Total	6,417	1,244	19

* Number from whom completed questionnaires were received.
§ For what constituted ½ day or less see text.

difficult to find data for comparison. From the figures available, the total number of individual hunters and the total man days of hunting effort in 1967 seem to have been quite similar to those in 1966. There does, however, appear to have been a slight difference in the distribution of the hunting pressure throughout the season. In 1967 slightly more people hunted during the early part of the season and somewhat fewer hunted during the latter part. But the major difference was the greater proportion of the hunters that possessed special antlerless deer licenses as a result of the increase in the number to be issued.

DEER SEEN Information concerning the number of live deer seen while hunting was obtained from the questionnaires that were returned and is summarized in Table 5. Although the proportion of the hunters that saw deer gives some measure of the opportunities for shooting a deer, the man days per deer seen are more meaningful.

TABLE 5. FREQUENCY OF DEER SEEN BY HUNTERS ON THE MOOSE RIVER AREA DURING THE 1967 SEASON

Period	Number of hunters*	Man days	Hunters who saw live deer		Total deer seen§	Man days per deer seen
			Number	Per cent		
October 25–October 29	3,642	6,905.5	932	26	2,064	3.3
October 30–November 5	963	1,482.5	175	18	409	3.6
November 6–November 12	874	1,382.0	203	23	448	3.1
November 13–November 19	367	476.5	69	19	129	3.7
November 20–November 26	329	469.0	85	26	169	2.8
November 27–December 5	242	290.0	110	45	251	1.2
Total	6,417	11,005.5	1,574	25	3,470	3.2

* Number from whom completed questionnaires were received.
§ Many deer undoubtedly seen more than once or by more than one hunter.

These figures take into consideration not only the number of hunters but also the time actually spent in the Area. At the beginning of the season the average time required to see a deer was more than 3 days. Despite the fact that roughly half the deer harvest occurred during the first period of the season, the time increased only slightly during the second period. During the third period it dropped below that for the first period, and, although it rose again during the next period, it dropped even more during the fifth period. Then, a definite change was recorded for the last period when 45 per cent of the hunters saw deer and on the average it took only 1.2 days to see a deer.

These data demonstrate that the chances of seeing a deer did not decrease as the season progressed. If the harvest of deer had produced a real change in population numbers, the amount of time required to see a deer would have increased. Apparently the removal of deer did not affect hunter success.

THE DEER HARVEST There were 497 deer taken on the Moose River Recreation Area during the 1967 season (Table 6). This compared with 162 in 1964, 203 in 1965 and 373 in 1966. The largest deer was a 6½-year-old buck that weighed 212 pounds (dressed weight). A 14-point head represented the greatest number of antler points.

TABLE 6. THE DEER HARVEST AND HUNTING EFFORT PER DEER TAKEN IN THE MOOSE RIVER AREA IN 1967

Period	Deer taken					Hunting effort (man days per deer)*
	Adult		Fawn	Total		
	Male	Female		Number	Per cent	
October 25–October 29	72	91	84	247	50	36.3
October 30–November 5	14	19	9	42	9	51.5
November 6–November 12	37	18	16	71	14	25.5
November 13–November 19	25	9	7	41	8	15.0
November 20–November 26	11	12	8	31	6	17.0
November 27–December 5	15	34	16	65	13	7.2
Total	174	183	140	497	100	29.3

* Derived from Table 3.

The distribution of the deer kill during the different periods of the season substantially followed the pattern of hunting pressure, with the heaviest pressure and highest kill during the period from October 25 to 29 followed by a sharp decline during the second period. Hunting success also decreased during the second period (the more man days required to shoot a deer, the poorer the success), but after that it increased greatly. The least amount of effort was needed to bag a deer during the last nine days of the season.

Although the number of deer taken during the first period was much greater than that during any other period, the average rate of success for the individual hunter was not high. Its increase after the second period may be correlated with a number of factors. Snow, which was present during most of this time, provided tracking opportunity and also made it easier to see deer. In mid-November the rutting season was at its height. There is also the possibility that more experienced hunters and those most familiar with the Moose River area tended to hunt toward the end of the season. Under these circumstances, the reduced hunting pressure itself could have been the chief factor in increasing hunting success.

Deer Kill According to Type of License The composition of the deer kill according to the type of license is summarized in Table 7. It is interesting that 15 (9 per cent) of the adult males could not

Table 7. Composition of the Deer Kill in the Moose River Area According to Type of License in 1967

Type of deer	Special Antlerless deer license	Big game license	Party permit	Total
Antlered male*	..	134	25	159
"Antlerless" male§	11†	..	4‡	15
Adult female	161	..	22	183
Fawn	133	..	7	140
Total				
Number	305	134	58	497
Per cent	61	27	12	100

* Antlers at least 3 inches long, the minimum legal size under big game license.
§ Antlers less than 3 inches long or shed.
† All yearlings, including one with its antlers broken off and one that had shed its antlers.
‡ Included two yearlings, one 2½ year old and one adult that had shed its antlers.

have been taken legally if hunting had been confiend to big game license holders. The role of the special antlerless deer license is quite evident since 61 per cent of the total harvest was taken by holders of these licenses. Some of these deer might have been taken under party permits, but only 8 per cent of the hunters possessed valid permits for the Area. Consequently, without the special licenses the harvest would have been less than half what it was. Hunting under the special license provided a means for hunters to take additional deer and increased the chances of attaining adequate population control.

Hunting Success Hunting success, in terms of the amount of time required to take a deer under different licenses, is summarized

TABLE 8. HUNTING SUCCESS ON THE MOOSE RIVER AREA IN 1967 IN TERMS OF THE TIME REQUIRED TO TAKE A DEER UNDER DIFFERENT LICENSES

Licenses	Deer taken		Hunting effort (man days)*	Hunting success (man days per deer taken)
	Type	Number		
Special antlerless deer license and party permit	antlerless	338†	7,852	23.2
Big game license and party permit	antlered§	159	14,542	91.5
Total		497	14,542	29.3

* Derived from data summarized in Table 3.
§ Antlers at least 3 inches long.
† Included 15 adult males, of which 12 had antlers less than 3 inches long, two had shed their antlers and one had its antlers broken off.

TABLE 9. SUCCESS OF HUNTERS HOLDING SPECIAL ANTLERLESS DEER LICENSES IN THE MOOSE RIVER AREA DURING DIFFERENT PERIODS OF THE SEASON IN 1967

Period	Number of hunters	Hunters successful	
		Number	Per cent
October 25–October 29	2,406	170	7
October 30–November 5	735	24	3
November 6–November 12	577	34	6
November 13–November 19	241	16	7
November 20–November 26	192	20	10
November 27–December 5	198	41	21
Total	3,293*	305	9

* Less than sum of figures for the several periods because some hunters hunted during more than one period.

in Table 8. Only a broad interpretation of these data can be made because of the possible combinations of licenses and permit. The total man days of hunting effort is used for antlered deer because all hunters had to have a big game license whether or not they also had a special antlerless deer license or party permit. Although a number of hunters were known to have come to the Area solely to hunt antlerless deer under the special license, no separate estimate of their effort is available. Of the total hunters, 46 per cent could hunt antlered deer only, while the remainder could hunt antlerless deer as well. These data indicate that the time required to take an antlered deer was about three times the average for all deer, whereas for antlerless deer it was slightly less than the average.

The success of the hunters who possessed special antlerless deer licenses is further analyzed in Table 9 according to the different periods of the season. Here again can be noted the concentration of hunting pressure during the first period, followed by a sharp drop and continued decline as the season progressed. The greatest rate of success among these hunters was experienced during the last two periods. Success during the first four periods was lower and rather uniform except for a noticeable decrease from October 30 to November 5. The over-all proportion who took deer during the 1967 season (9 per cent) was less than that (12 per cent) in 1966.

Another means of presenting hunter success is in terms of the ratio of hunters to deer harvested. Since there were 6,457 individual hunters present during the 1967 season and a total of 497 deer were harvested, the average ratio was 13 to one. Actually, hunter success was somewhat less because some hunters took more than one deer. No directly comparable figures are available for comparison. The statewide average is one deer to seven hunters, but this includes all the hunting that individual hunters do throughout the season in a number of different areas. The Moose River figure represents only hunting that took place on the Area. Probably most of those who hunted there hunted in other places also, since over half of them hunted in the Area only during the first five days of the season. It is concluded that hunting success in the Moose River area during the 1967 season was very good.

Deer Kill Locations A major consideration in assessing the success of the 1967 deer season in the Moose River area is the distribution of the locations where deer were killed. These were plotted on grided topographical maps and are shown in Figure 1.

It was found that 79 per cent of the deer were shot within a mile of a road open to vehicles other than snow machines. Of the 103 deer that were taken more than a mile from a road, 55 were adult males and constituted 32 per cent of all the adult males taken. This can probably be attributed to the hunters, primarily seeking bucks, who hunter farther back from the roads and thus met with greater success.

The map also reveals that 480 deer, or 97 per cent of the total harvest, came from some 79 square miles, or about 60 per cent, of the Area. A substantial portion of the Area was not hunted at all. Furthermore, many sections of the 79-square-mile portion that produced 97 per cent of the kill received very light or even negligible hunting pressure. It is apparent that access played a major role in the kill distribution and very likely in the hunter success rate and total harvest.

The road network extending south from the Otter Brook checking station was open only to four-wheel-drive vehicles. A total of 180 deer, or 36 per cent of the total harvest, came from this area. However, 43 per cent of the adult males, but only 29 per cent of the fawns, were taken there.

The density of the kill can be calculated in several ways. If only the area that produced the bulk (97 per cent) of the harvest is considered, a kill of about six deer per square mile was achieved. If the total area where deer could be taken under special antlerless deer licenses is used the take was about four per square mile. If a figure is derived by considering drainages and the probability that some deer were taken along the margins of the Area through other hunter-access points, it would be intermediate. In recent years the legal deer kill for all of Hamilton County has ranged from 1.6 to 2.2 deer per square mile. Consequently, the Moose River area during the 1967 season produced a harvest over twice as large as the average for Hamilton County.

PHYSICAL CONDITION OF DEER Deer taken in the Moose River area have been examined for four successive seasons. Younger deer with the greatest growth possibilities are most affected by range conditions that are less than optimum. The information recorded each year on antler beam diameter, antler points and dressed weight for the younger deer (less than 4½ years old) is given in Table 10. The figures for 1964 serve as a base with which to compare changes in the

TABLE 10. COMPARISON OF INDICES OF PHYSICAL CONDITION FOR YOUNG DEER TAKEN ON THE MOOSE RIVER AREA FROM 1964 TO 1967

Sex	Age (years)	1964		1965		1966		1967	
		Sample	Average	Sample	Average	Sample	Average	Sample	Average
		Antler beam diameter (millimeters)*							
Male‡	1½	20	15.5	23	15.5	42	14.5	34	14.1
	2½	16	24.2	23	21.4	46	20.2	52	20.9
	3½	4	27.0	12	26.8	35	26.3	35	25.4
		Antler points (number)§							
Male	1½	20	2.8	23	3.1	44	2.6	34	2.4
	2½	16	6.9	24	5.5	46	5.3	52	5.2
	3½	4	7.5	12	7.8	35	7.4	35	7.3
		Dressed weight (pounds)†							
Male	½	5	59.1	..	..	25	57.9	39	57.3
	1½	16	102.2	..	..	52	98.3	36	89.9
	2½	14	137.5	..	..	43	122.3	35	124.4
Female	½	11	61.4	..	..	30	54.0	38	52.6
	1½	9	92.0	..	..	35	87.9	13	83.5
	2½	9	105.0	..	..	31	96.1	26	96.4

* Measured about 1 inch above the burr.
§ Counted only if point extended at least 1 inch from near edge of beam.
† Hog-dressed, i.e., heart, liver, lungs and intestines removed. Data for 1965 insufficient.
‡ Samples included 1½-year-old males with antlers less than 3 inches long as follows: 1964-1; 1965-2; 1966-11; 1967-11.

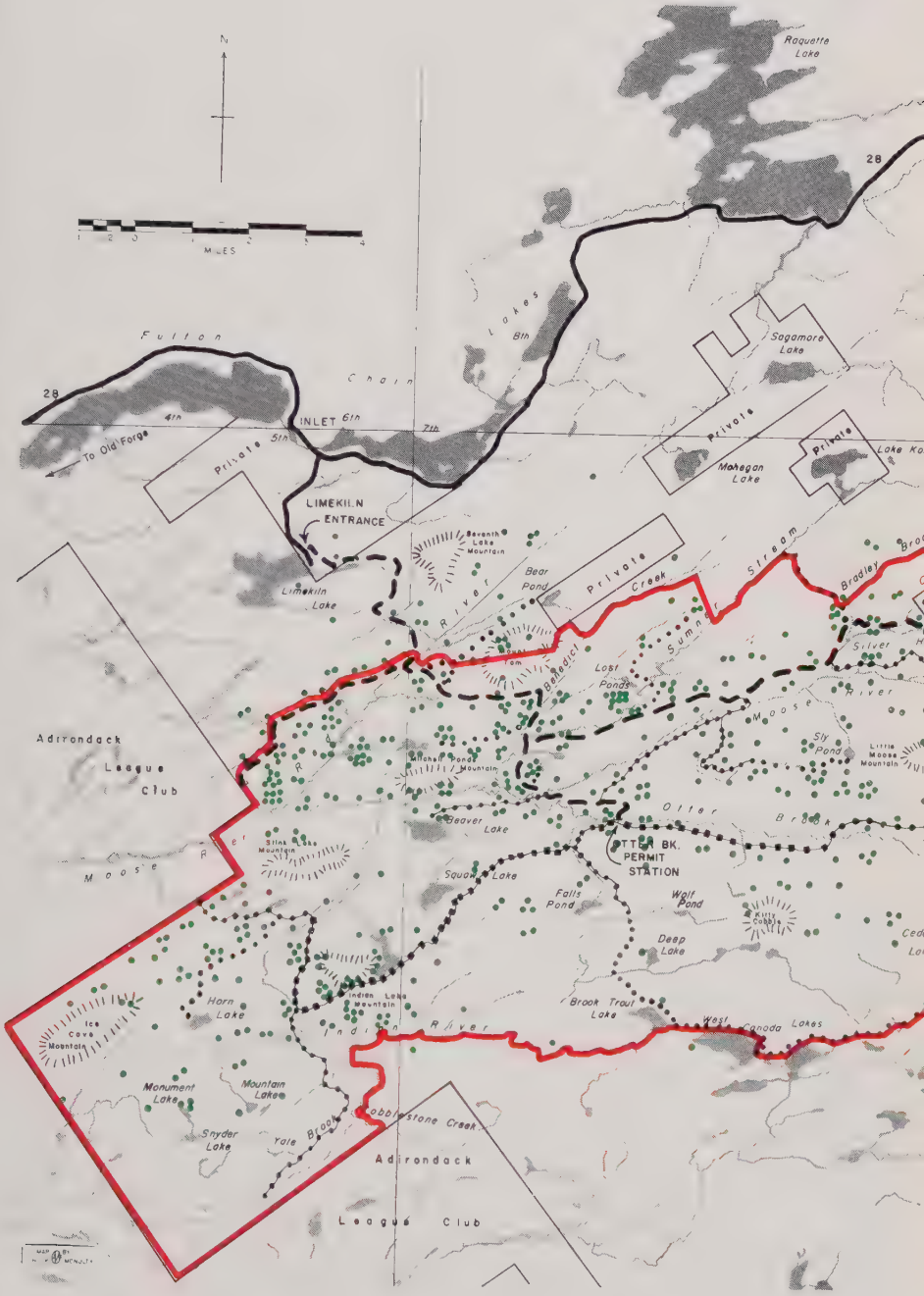
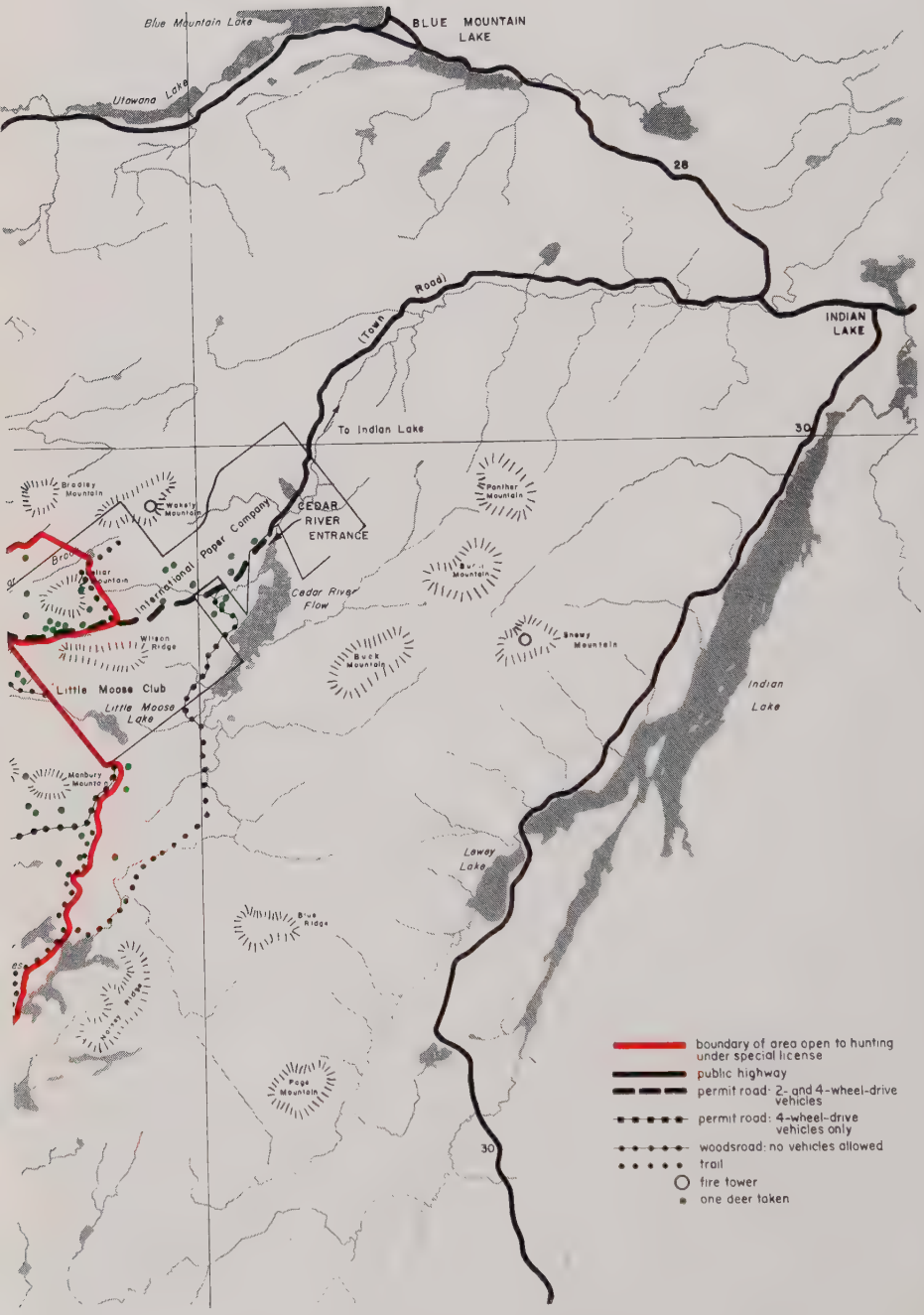


Figure 1. Map of Moose River Recreation Area and vicinity showing area open to hunting



under special antlerless deer license in 1967 and locations where deer were taken.

physical condition of deer from the Area. However, weight and antler size for these age groups were small in relation to those for deer on high quality range.

In 1966 and 1967 weights and antler sizes were lower than in 1964. Also there was a great increase in the number of yearling bucks (1½ years old) with antlers less than 3 inches long, despite the increase in the number of antlerless deer harvested. The decrease from 1966 to 1967 in antler size among 1½-year-old males and in weight among fawns and 1½-year-old males and females was not enough to be alarming. However, should the downward trend in size continue, it would indicate a deterioration in range conditions in relation to the population present.

The indices of physical condition for the four years indicate that a decline may have begun, associated with a take of only 162 deer in 1964, 203 in 1965 and 373 in 1966. Furthermore, in the springs of 1965, 1966 and 1967, winter losses of 9.7, 14.2 and 6.6 dead deer per square mile were found on the areas surveyed although the winters were generally mild. So the total losses substantially exceeded the recorded harvest by hunting. One can only speculate, but it seems reasonable to assume that a greater decline in physical condition would have been evident if these deer had not been harvested.

Population Changes In the fall a deer population comprises a large number of fawns and progressively decreasing numbers among the older age groups. One of the great natural hazards confronting deer in the Adirondack region is to survive their first winter when they are 7 to 10 months old. These fawns are usually the smallest deer in the population. Female fawns generally are smaller than males fawns, and, where heavy competition for food occurs in winter, they are less able to compete and die in larger numbers than the males.

During the hunting season, yearling deer represent the fawns of the previous year. When overwinter survival has been good, yearlings are usually 20 to 40 percent more numerous than 2½ year olds. A lower proportion indicates poor surival. Because female fawns do not survive as well as males, when starvation occurs the proportion of yearling females is usually lower than that of yearling males in relation to the 2½ year olds in the surviving population.

The age composition of the deer taken in the Moose River area from 1964 to 1967 is shown in Table 11. Among males the proportion of yearlings was good in 1964 and 1966 and poor in 1965 and 1967. Among females it was low during each of the first three years and extremely low in 1967. It is obvious there were substantial losses among male fawns in 1966-67 and even greater losses among female fawns.

TABLE 11. AGE COMPOSITION OF DEER TAKEN ON THE MOOSE RIVER AREA FROM 1964 TO 1967

Age (years)	1964		1965		1966		1967		Total		
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Per cent*
Male											
10½	..	..	..	..	..	..	2	1.1	2	0.4	0.3
9½	1	1.4	..	..	1	0.6	1	0.6	3	0.6	0.5
8½	1	1.4	1	0.9	1	0.6	2	1.1	5	1.0	0.8
7½	4	5.4	11	9.7	2	1.2	3	1.7	20	3.8	3.1
6½	4	5.4	7	6.2	4	2.5	5	2.9	20	3.8	3.1
5½	3	4.0	8	7.1	4	2.5	6	3.5	21	4.0	3.3
4½	7	9.5	3	2.7	14	8.6	14	8.1	38	7.2	5.9
3½	5	6.7	17	15.0	35	21.5	37	21.3	94	17.9	14.5
2½	21	28.4	33	29.2	46	28.2	54	31.0	154	29.4	23.8
1½	28	37.8	33	29.2	56	34.3	50	28.7	167	31.9	25.8
Sub-total	74	100.0	113	100.0	163	100.0	174	100.0	524	100.0	xxx
½	7	..	17	..	33	..	65	..	122	..	18.9
Total....	81	..	130	..	196	..	239	..	646	..	100.0
Female											
10½	1	1.5	3	5.2	1	0.7	..	..	5	1.1	0.8
9½	4	5.8	3	5.2	4	2.8	5	2.7	16	3.5	2.7
8½	5	7.2	4	6.9	5	3.5	9	4.9	23	5.1	3.9
7½	5	7.2	4	6.9	14	9.8	13	7.1	36	7.9	6.1
6½	5	7.2	3	5.2	4	2.8	10	5.5	22	4.9	3.7
5½	6	8.7	6	10.3	3	2.1	11	6.0	26	5.7	4.4
4½	9	13.1	5	8.6	12	8.4	15	8.2	41	9.1	7.0
3½	6	8.7	10	17.2	25	17.5	46	25.1	87	19.2	14.8
2½	13	18.9	9	15.5	37	25.9	47	25.7	106	23.4	18.0
1½	15	21.7	11	19.0	38	26.5	27	14.8	91	20.1	15.5
Sub-total	69	100.0	58	100.0	143	100.0	183	100.0	453	100.0	xxx
½	12	..	15	..	34	..	75	..	136	..	23.1
Total....	81	..	73	..	177	..	258	..	589	..	100.0

* Fawns included in deriving percentage.

Since the winters during these years had been mild, these losses reflected the overpopulation that was developing.

The annual harvest of deer each fall removes some from each age group. Other causes of death (crippling loss, predator loss, starvation, etc.) remove additional deer. Winter losses among adults are heaviest among deer 8½ years old and older. Very few deer live beyond 10½ years in the central Adirondacks. When the total mortality among adult deer is excessively high there will be relatively few deer more than 4½ years old left in the population, and they become scarce in the harvest. Those 7½ years old and older are the first to disappear.

The data in Table 11 show that in the Moose River area male deer 7½ years old and older comprised 8.2, 10.6, 2.4 and 4.5 per cent of those taken in 1964, 1965, 1966 and 1967, respectively. The decrease indicates that the annual take of bucks in these years was greater than that in years previous to 1964. But the total mortality was not too heavy and would not be considered so until there were no males more than 4½ years old left in the population.

For females, the corresponding proportions of older deer for the four years were 21.6, 24.2, 16.8 and 14.7 per cent, respectively.

Although they were greater than those for males, they also exhibited some decrease during the four-year period and indicated that total mortality was greater than that prior to 1964.

Two features of these data have an important bearing on deer management. First, winter losses occurred among fawns and were heaviest during 1966-67. Second, among the adults the harvests by hunting and all other losses combined were not large enough to prevent substantial numbers from attaining the ages at which many die of old age during the winter. Both of these conditions are undesirable because, under proper management, the harvest of both males and females should be sufficient to allow very few females and even fewer males to reach the age of 8½ years. By reducing population density during the fall such harvests would result in less competition and facilitate a higher overwinter survival of fawns. Despite the fact that hunting on the Area in 1967 was considered good, it is felt that more deer should have been removed and that substantially more male deer and considerably more female deer should be harvested in the future. The age-composition data for 1967, together with those for the preceding three years, will serve as a basis of comparison for judging the adequacy of future harvests.

BEAR KILL

A total of 15 bears were taken during the 1967 season, equaling the number taken in 1966. Of these, 10 were females and five were males. Ten were taken during the first five days of the season, and the remainder were taken at scattered times through November 11, although bear tracks were observed up to Thanksgiving. Only eight of the bears were weighed, with the heaviest being 188 pounds.

CONCLUSIONS

The total deer harvest during the 1967 season in the Moose River Recreation Area was encouraging, hunting success was relatively good and a minimum of problems was encountered. Nonetheless, there is much room for improvement in the management of this deer population. Until adequate harvests are achieved, overpopulation of the winter range will continue.

A number of obstacles have prevented deer harvests sufficient to hold the population in balance with the carrying capacity of the winter range. First, too few of the hunters that came to the Area had special antlerless deer licenses or party permits. Many hunters who possessed only a big game license had the opportunity to shoot an antlerless deer. The records indicate that having a license or permit for taking antlerless deer quadrupled a hunter's chances of going

home with a deer. Second, there was a marked concentration of hunting pressure during the first period of the season. Maintenance of at least moderate pressure after that should result in a more adequate harvest since the data indicate that hunting success increased significantly during the last four weeks. There is also a need for better hunter distribution throughout the Area. Some sections produced very high harvests, while others were not hunted at all. This is partly an access problem which might be solved by improving the roads and trails. However, it is hoped that as the hunters become more familiar with the terrain they will penetrate into the sections farther from the roads. The Moose River country is a very difficult one to hunt, let alone travel in, due to the dense stands of secondgrowth that have developed since the 1950 blowdown and from the lumbering of the Gould tract. But, if one makes the effort to become familiar with the lay of the land, he can be rewarded with some excellent hunting.

The results of this and the three preceding hunting seasons in the Moose River area have done much to demonstrate the harvest potential that exists and to strengthen the belief that the deer range in the central Adirondacks generally is capable of sustaining much higher harvests than have been achieved in the past.

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MINIMUM DEER POPULATIONS ON THE MOOSE RIVER RECREATION AREA

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ABSTRACT

Using data from the Moose River Recreation Area, a method for calculating the minimum population of deer on an area is described. It is based on records of the age and sex distribution of the deer taken by hunting coupled with information on applicable rates of reproduction. No allowance is made for animals that may have been present but lost through other causes of mortality. Minimum populations for the Moose River area in 1964, 1965 and 1966 are given as well as the number of deer taken by hunting each year from 1964 to 1967 according to year class. Although actual populations would obviously be greater, such minimum figures are useful as a documented baseline to which may be added whatever estimates seem warranted for other losses.

Knowledge of the size of the deer population on an area is important to planning management and interpreting its results. Data for deer taken by hunting afford a means of determining the size and composition of the minimum population involved.

"Minimum population" represents the number of deer that can be accounted for directly from the age and sex distribution of those taken by hunting coupled with information on applicable rates of reproduction. It excludes any allowance for animals that may have been present but lost through causes of mortality for which specific data are lacking. Thus, being documented and undisputably conservative, it is useful as a baseline for management purposes. From it, one may calculate what the actual population may have been by adding whatever estimates seem warranted for other losses.

Data for the Moose River Recreation Area may be used to illustrate a method by which such a minimum population may be calculated.

MINIMUM POPULATION IN 1966

The population in 1966 has been selected as the primary example because the age distribution for both sexes among the deer taken is considered representative of the usual composition of populations there. In some years, as happened in 1967 when the proportion of yearlings (especially females) in the take was abnormally low, the age composition of a population may be such that use of the method would give a distorted result.

Hunters on the Area were required to bring out their deer through one or the other of two checking stations. All deer taken were tallied, and most of these were examined by Department technicians although a few were brought out when no technician was present. For those examined, age as determined from the condition of

the teeth (Severinghaus, 1949), sex, antler size and dressed weight were recorded. The age and sex distribution of the deer that were not examined was considered to have been the same as among those that were examined.

The minimum population was derived from data for the adult males taken by applying factors representing the other components of the population. In a stable population the number of yearlings entering it each fall is equal to the total annual losses among adults. Assuming a random harvest, the proportion of yearlings among adult males taken would be approximately the same as the proportion for total losses among adult males in the population as a whole (Severinghaus, 1960, 1961). In the present instance, hunting was considered to be the only source of loss, and, for adult males, the proportion of yearlings in the take was applied to the total taken to obtain the total number present at the beginning of the hunting season. The corresponding number of adult females was determined from the sex ratio for the adults derived according to the method described by Severinghaus and Maguire (1955) in which the ratio of the percentages of yearlings in separate samples of the two sexes (i.e., those recorded at the checking stations), corrected for any inequality in their sex ratio, is the inverse of the sex ratio among the adults as a whole. The sex ratio for yearlings, used as a correction factor, was 106.2 males per 100 females, the same as that among fawns as given by Severinghaus and Cheatum (1956, p. 66). The rate of reproduction used was 1.5 fawns per adult female (2 years old or older in the spring), with no

Table 1. Age Distribution by Sex for Deer Taken on the Moose River Area in 1966

Age (years)	Male		Female	
	Number	Per cent	Number	Per cent
1½	56	34.3	38	26.5
2½	46	28.2	37	25.9
3½	35	21.5	25	17.5
4½	14	8.6	12	8.4
5½	4	2.5	3	2.1
6½	4	2.5	4	2.8
7½	2	1.2	14	9.8
8½	1	0.6	5	3.5
9½	1	0.6	4	2.8
10½	0	0.0	1	0.7
Sub-total	163	100.0	143	100.0
½	33	..	34	..
Total	196	..	177	..

reproduction from younger animals, as recorded for the Area in 1964 (Severinghaus, 1964).

The age distribution for the deer taken is given in Table 1. The minimum population prior to the hunting season may be derived from these data.

Minimum Number of Adult Males

Since yearlings comprised about one-third (34.3 per cent) of the adult males taken, the total number of males in the population would

Table 2. Age and Sex Composition of the Minimum Deer Population on the Moose River Area Prior to Hunting Season in 1966

Age (years)	Male	Female	Total
1½	168	158	326
2½	138	155	293
3½	105	104	209
4½	42	50	92
5½	12	13	25
6½	12	17	29
7½	6	58	64
8½	3	21	24
9½	3	17	20
10½	0	4	4
Sub-total	489	597	1,086
½	339	319	658
Total	828	916	1,744

have been three times the number taken, i.e., 489 (163 x 3). The caluculated figures for all age groups are shown in Table 2.

Minimum Number of Adult Females

Among the adult males examined, 34.3 per cent were yearlings, and for the females the proportion was 26.5 per cent. Applying the correction factor (1.062) for the difference in sex ratio among yearlings results in a value of 32.3 per cent for males. Dividing this by the value for females gives a sex ratio of 1.22 females per male among the adults as a whole. Applying this to the calculated total for males (489) gives a corresponding figure of 597 for the total number of adult females. The calculated figures for all age groups are shown in Table 2.

Minimum Number of Fawns

Because studies (Severinghaus, 1964) had shown no reproduction among females less than 2 years old (in the spring), the 158 yearlings

were excluded as breeders. At the reproduction rate of 1.5, the 439 remaining adult females would have produced 658 fawns. According to the sex ratio used, these would have comprised 399 males and 319 females (Table 2).

Total Minimum Population

The sum of these several components (1,744) represents the total minimum population prior to the hunting season in 1966. It is a conservative figure, not only because the method of calculation made no allowance for deer lost from causes other than hunting, but also because in substantial portions of the Area hunting was negligible due to relative inaccessibility.

Minimum Populations in Earlier Years

Hunting on the Moose River Recreation Area, under regulations whereby records of the number of deer taken and of their age and sex were obtained, was also done in 1964 and 1965. The records are summarized in Table 3. From these data, minimum populations for these years could be calculated by the method described. However, an even more conservative method is to add these figures, according to their respective year classes, to those in Table 2. For example, the deer taken as 2½ year olds in 1966 must have been present as 1½ year

Table 3. Age Distribution by Sex for Deer Taken on the Moose River Area in 1964 and 1965

Age (years)	1964				1965			
	Male		Female		Male		Female	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
1½	28	37.8	15	21.7	33	29.2	11	19.0
2½	21	28.4	13	18.8	33	29.2	9	15.5
3½	5	6.8	6	8.7	17	15.0	10	17.2
4½	7	9.5	9	13.0	3	2.7	5	8.6
5½	3	4.1	6	8.7	8	7.1	6	10.3
6½	4	5.4	5	7.3	7	6.2	3	5.2
7½	4	5.4	5	7.3	11	9.7	4	6.9
8½	1	1.3	5	7.3	1	0.9	4	6.9
9½	1	1.3	4	5.8	0	0.0	3	5.2
10½	0	0.0	1	1.4	0	0.0	3	5.2
Sub-total	74	100.0	69	100.0	113	100.0	58	100.0
½	7	..	12	..	17	..	15	..
Total	81	..	81	..	130	..	73	..

TABLE 4. AGE AND SEX COMPOSITION OF THE MINIMUM DEER POPULATION, ACCORDING TO YEAR AND CLASS, ON THE MOOSE RIVER AREA PRIOR TO THE HUNTING SEASON IN 1964, 1965 AND 1966

Year class (year born)	1964		1965		1966	
	Male	Female	Male	Female	Male	Female
1954	0	1	..	..	..	..
1955	1	7	0	3	..	..
1956	1	12	0	7	0	4
1957	8	26	4	21	3	17
1958	18	30	14	25	3	21
1959	16	67	13	61	6	58
1960	27	32	20	23	12	17
1961	20	24	15	18	12	13
1962	80	73	59	60	42	50
1963	166	128	138	113	105	104
1964	178	178	171	166	138	155
1965	..	..	185	173	168	158
1966	..	..	..	..	339	319
Total by sex						
Adults	337	400	434	497	489	597
All deer	515	578	619	670	828	916
Total	1,093		1,289		1,744	

olds in 1965 and as fawns in 1964; therefore, they represented the 1964 year class. Thus, for this year class, the males taken in 1966 plus those taken in 1965 (138 + 33 = 171) would have been the minimum number present in 1965; and that total plus those taken in 1964 (171 + 7 = 178) would have been the minimum number present in 1964. The figures for each year class represented in 1966, back-calculated in this way, are given in Table 4.

TOTAL DEER HARVEST

Of interest in connection with these calculations of the minimum population is the record of the deer positively known to have been taken by hunting on the Area from 1964 to 1967 (Table 5). The figures for 1967 are included here even though they could not be used for calculating a minimum population for that year. The data are arranged according to year class so that the record for each can be followed separately. Of the 1,235 taken, 724 must have been present in 1964. This is lower than the number given in Table 4 because the latter was derived from the calculated figures for 1966 which included deer that had not been removed. Those present prior to the hunting season of 1964 included 495 adults and 229 fawns.

Table 5. Number of Deer Taken by Hunting on the Moose River Area from 1964 to 1967 According to Year Class

Year class	Year taken										Total taken
	1964		1965		1966		1967		Total		
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
1954	..	1	..	..	..	..	..	..	..	1	1
1955	1	4	..	3	..	..	..	..	1	7	8
1956	1	5	..	3	..	1	..	..	1	9	10
1957	4	5	1	4	1	4	2	..	8	13	21
1958	4	5	11	4	1	5	1	5	17	19	36
1959	3	6	7	3	2	14	2	9	14	32	46
1960	7	9	8	6	4	4	3	13	22	32	54
1961	5	6	3	5	4	3	5	10	17	24	41
1962	21	13	17	10	14	12	6	11	58	46	104
1963	28	15	33	9	35	25	14	15	110	64	174
1964	7	12	33	11	46	37	37	46	123	106	229
Sub-total*									371	353	724
1965	..	..	17	15	56	38	54	47	127	100	227
1966	..	..	..	..	33	34	50	27	83	61	144
1967	..	..	..	..	..	..	65	75	65	75	140
Total by sex	81	81	130	73	196	177	239	258	646	589	1,235
Total by year	162		203		373		497		1,235		1,235

* Minimum number that must have been present at beginning of hunting season in 1964.

DISCUSSION

Reliability of the method used to calculate the minimum population in 1966 depends on the validity of the age assignments made for deer examined and of the factors applied to the resultant data. The accuracy of the technique for judging age has been well established, and personnel at the checking stations were competent in using it. Deviation of the sex ratio among adults from that for yearlings is considered sound provided there is no great abnormality in the proportion of yearlings among either the males or females as a whole. The rate of reproduction used was that recorded in the autopsy of a substantial sample of female deer collected on the Area in the winter of 1963-64.

As has been pointed out, the calculated populations are based solely on deer killed during the hunting season and brought out through the checking stations. They take no account of deer that were killed and eaten in camp or removed from the area without being counted, deer that were wounded and died but were not recovered, or deer that died from predation, winter starvation or other miscellaneous causes. To arrive at a true population, such deer, as well as their progeny, would have to be added. And the deer added in any year class in a given year would have to be included in all previous years applicable to that year class. No attempt has been made to do this, but it is obvious that a substantial number of deer would be involved.

Some information, however, is available concerning winter losses. Small-scale sampling surveys of a few square miles of the area, chiefly the major deer wintering grounds, have been made during the spring for many years. The purpose has been to assess the trend in winter mortality from year to year, not to measure its total magnitude. The records include deer that died of starvation and deer that succumbed from other causes. The caracsses counted (including carrionized remains with bones, hide and hair) represented the accumulation from early fall (September) until the time of survey (late May or early June). Remains that had decayed and weathered during the summer were not included. The results from 1930-31 to 1962-63 were summarized by Severinghaus (1964). Some of those data and the results of more recent surveys are given in Table 6. Although losses from

TABLE 6. RELATIVE DEGREE OF WINTER MORTALITY AMONG DEER IN THE MOOSE RIVER PLAINS AND VICINITY

Winter	Cause of mortality and number per square mile surveyed		
	Starvation	Other	Total
1956–57	*	*	*
1957–58	8.8	3.5	11.3
1958–59	13.0	8.4	21.4
1959–60	20.0§	11.0§	31.0§
1960–61	0.0	2.1	2.1
1961–62	0.0	6.2	6.2
1962–63	2.6	0.0	2.6
1963–64	*	†	..
1964–65	0.0	9.7	9.7
1965–66	0.0	14.2	14.2

* Negligible
§ Approximate
† Omitted because of collection of specimens for autopsy in February.

causes other than starvation would be less associated with the winter range, the rates recorded cannot be applied to the Area as a whole. Nevertheless this is further evidence that the minimum populations calculated do not include a large number of deer that actually were present.

Finally, the calculated population figures are conservative because hunting on the Area was concentrated in the vicinity of the roads. Large sections of the interior were hunted very little, if at all. Consequently, parts of the deer population present were not well represented in the records of deer taken.

The procedures described afford a means of calculating the minimum deer population on the Moose River Recreation Area in recent

years. They may be used similarly for other areas if the pererequisite data concerning the age and sex distribution of deer taken by hunting are available. The results frequently indicate a larger population than most hunters believe to be present. Nevertheless, because of elements of a population that are purposely omitted from the calculations, it can be demonstrated that the actual number of deer must have been even greater. Comparison with actual harvests in various areas where essentially the same method has been used during the past 20 years has corroborated the fact that such calculated figures are conservative.

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THE ECOLOGICAL DECLINE OF LAKE ERIE

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ABSTRACT

Changes in Lake Erie due to natural processes and the activities of man are discussed with respect to geology, hydrology, pollution, chemistry, plankton, benthos and fisheries. In all of these areas, it is shown that many changes have taken place and that the rate of change has accelerated in recent years. Most of these changes are harmful to the lake's value as a resource for man and as a habitat for its natural fauna. Several proposed ideas for reversing this trend are reviewed.

In recent years, interest in the pollution and degredation of natural waters has become widespread and fashionable among both scientific and popular writers. In such writings, it is common to apply the label of "eutrophication" to the deterioration process, whatever its cause and means. To the classically-trained limnologist, "eutrophication" refers only to an increase in nutrient content, not to aging of lakes in general, nor to most types of pollution (Beeton, 1966). For examples of eutrophy, one usually turns to small, shallow, weed-choked lakes and ponds, and it is indeed in such environments that the typical conditions are most easily seen. On the other hand, large lakes are the classic examples of oligotrophy, or low nutrient conditions. It has been widely held that the vast dilution factor characteristic of the largest lakes would prevent any clear indication of eutrophy in them (Davis, 1964). Recent studies, however, have forced a reconsideration of this idea. Perhaps the best-documented case is that of Lake Erie, the 11th largest lake in the world in surface area. From the human viewpoint, this lake is rapidly deteriorating, not only by becoming more eutrophic, but in other ways to be discussed in this paper.

GEOLOGICAL AND PHYSICAL CHANGES

Early Lake Erie was formed about 12,400 years ago. Its level was about 30 meters below that at present, but it rose rapidly when the area around its outlet at Buffalo was uplifted following the retreat of the last glacier. The present level of about 174 meters above the sea was attained 9,000 to 10,000 years ago and has changed little since (Lewis *et al.*, 1966). The hard rock at Niagara Falls controls the level of the lake by preventing vertical erosion of the outlet, acting as a natural weir. However, the falls are being eroded away horizontally and thus are moving upstream. It is estimated that this horizontal erosion will intersect the eastern basin of the lake in approximately

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25,000 years at the present rate. The lake will then empty, leaving little more than a marshy stream. By that time, however, other processes now becoming apparent will have destroyed the lake for human enjoyment, unless they are checked.

At present, the lake consists of three basins (western, central and eastern) that become less productive and deeper from west to east (Figure 1). The central basin is generally considered as the area between a line connecting Point Pelee (Ont.) and Sandusky (Ohio) and a line extending from the base of Long Point (Ont.) to Presque Isle (near Erie, Pa.). The western basin includes the island area and is nowhere deeper than 18 meters. It is almost always completely mixed by wind action and is the most productive of the three basins. The central basin has a maximum depth of slightly less than 30 meters and exhibits summer stratification, as does the eastern basin which has a maximum depth of 64 meters. The mean depth of the lake as a whole is less than 28 meters. Average depths of the other Great Lakes are much greater, particularly in proportion to their areas.

The chief process in the aging of a lake is filling with sediments. This is a serious problem in Lake Erie despite its large volume. All of the large tributaries and most of the allochthonous material enter the lake in the western basin, tending to decrease further its already shallow depth by adding sediments. Although the Detroit River (outlet of the upper lakes) contributes 90 per cent of the inflow (55,000 cubic meters per second), the Maumee River contributes most of the silt load and nutrients (Verduin, 1964). This is largely due to the draining of the Great Black Swamp in the late 19th century, which created extensive rich but easily eroded farmlands. Most of the northern and some southern shores consist of high clay cliffs subject to wave erosion which contributes large amounts of sediments to all three basins. The shore of the lake is sinking at a rate of about 1 meter per 300 years (Hartley, 1958) due to shifting of the earth's crust, and this increases erosion and sedimentation. In addition to man's acceleration of sedimentation through cultivation and abuse of the land, he has built harbor jetties and erosion-control structures all along the shore. These seem to have increased the total shore erosion and silt load (Hartley, 1958). There seem to be no published estimates of the rate of filling of the lake with sediments. The sediment load is reflected in light-penetration readings. In the Maumee River, Secchi disc readings average less than 1 meter. In the open water of the western basin, this increases to 2 meters due to mixing with the relatively clear water of the Detroit River and water from the central basin which enters through the Bass Island passages. Except for temporary seiche effects, there is a clockwise circulation of the waters

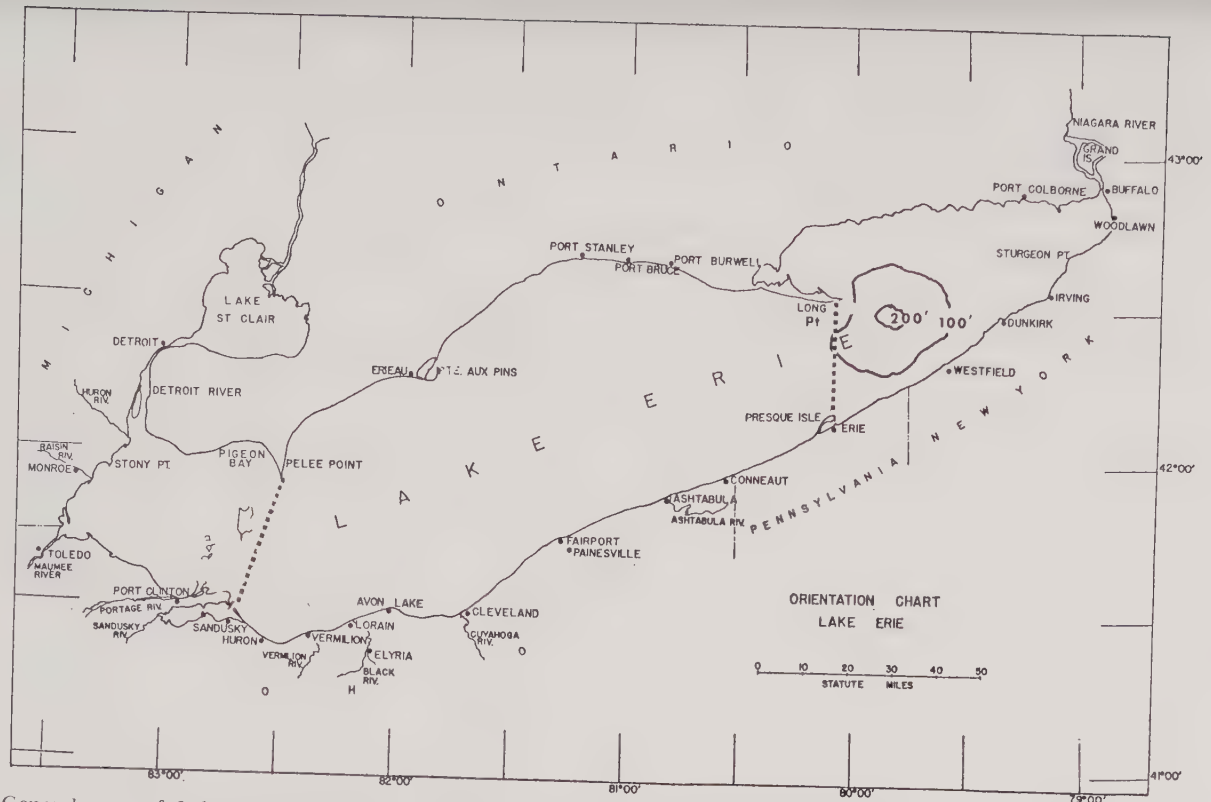

Figure 1. General map of Lake Erie showing the dividing lines between basins and 100-foot depth contours. (Modified from Powers *et al.*, 1960)

of the western basin, and all of the outflow is through the Pelee Passage along the north shore (Hartley *et al.*, 1966.) The average turnover time for western basin water is 2 months (Verber, 1955; Verduin, 1964). By the time the water reaches the eastern basin, its transparency has increased greatly, so Secchi disc readings are 4 to 8 meters (VanMeter and Shepherd, 1967). The latter readings are characteristic of the other Great Lakes; only western Lake Erie is not relatively clear. There have been no significant changes in transparency since the 1920's (Beeton, 1961), but an over-all average increase of 50 per cent in turbidity occurs from summer to early winter each year (Pinsak, 1967).

There has been a gradual warming of both the lake and the climate of the surrounding area. The increase in average lake temperatur has amounted to about 2° F. since 1920, and there have been several open winters recently (Beeton, 1961; Anonymous, 1967b). This is not necessarily a sympton of eutrophication, but contributes to it by accelerating biological processes and to some extent by making the habitat less favorable for some species and more favorable for others.

POLLUTION

Pollution, in the broad sense, is responsible for most of the changes in the chemistry of Lake Erie. Three kinds of pollution may be considered important to the lake: (1) silt, as already mentioned, which changes the character of the bottom and reduces light penetration; (2) domestic sewage, which adds nutrients, lowers dissolved oxygen and causes health problems; and (3) industrial wastes, which may do all of the foregoing as well as cause injury or death to living organisms. Serious pollution enters the lake from the lower Detroit River, the western shores, along the south shore and at the eastern end. Vessels on the lake and dredging operations also contribute significant amounts of pollution (International Joint Commission, 1951).

Most of the effects of domestic sewage are seen in the western basin. This area is particularly susceptible to pollution for three reasons: (1) the large industrial communities on the Maumee, Rasin and Detroit Rivers; (2) its shallowness and consequent small water volume; and (3) its semi-isolation caused by two peninsulas and numerous islands which tend to prevent free outflow of water to the rest of the lake. Each day, the American shore discharges 32 million kilograms of waste solids plus 228,000 kilograms of dissolved phosphate and nitrogen into the Detroit River. On the Canadian side, much of Windsor's sewage is dumped into the river without chemical treatment (Anonymous, 1967a). The same is true for the wastes of over 13,000 persons on the Michigan shore alone. The population in this area is

increasing at the rate of 26 per cent per decade (League of Women Voters, 1966), and the bacterial load at the outlet of the Detroit River has increased more than threefold since 1913 (Beeton, 1961). Maximum coliform counts in the area now reach 500 per milliliter, whereas in 1913 they were approximately 2 per milliliter (League of Women Voters, 1966; Beeton, 1961). In all, the Detroit River receives 6.1 billion liters of waste per day (Powers and Robertson, 1966).

Apparently there has been little if any increase in bacterial load in the central and eastern basins, except along populated shores. In a report on an early eastern basin survey, Zillig (1929) wrote: "The presence of *B. coli* in such small numbers, the repeated absence of this species and other gas-forming organisms in some parts of the lake, and the low bacterial counts at all stations, tend to eliminate pollution as a factor affecting fish in the open waters of Lake Erie". Recent open-water samples in the eastern and central basins have shown similar results (International Joint Commission, 1951).

Little detailed documentation is available for the industrial waste discharges into Lake Erie, but they are known to be of increasingly large magnitude, and are probably responsible for many of the increases in dissolved ionic material in the lake. A significant amount of these wastes is in the form of airborne particles from smokestacks and trash burning which settle on the lake. Nitrogen in particular seems to be added in this way.

CHEMICAL CHANGES

Except for the two constituents (Si and Fe) known to be involved in the mineral nutrition of at least some of the phytoplankton, all the chemical constituents of Lake Erie have increased during the past century (Ayers, 1962). Beeton (1961) summarized the changes in the major ions since 1906 as follows:

Ca	from	31.0	to 36.7	ppm
Mg	from	7.6	to 10.2	ppm
Na+K	from	6.5	to 9.4	ppm
SO_4	from	13.0	to 23.0	ppm
Cl	from	8.7	to 26.0	ppm
Si	from	5.9	to 1.6	ppm
Total solids	from	133	to 183	ppm

(Not all the values are from the same location, but the differences are minor compared with the total change in concentration). Verduin (1964) listed the following additional changes between 1950 and 1961 for the western basin only:

pH from less than 8.7 to 9.2

CO_2 from 32 μM/1 to 70 μM/1 (change per day at surface)

NO_3 from 1400 μg/l to 2200 μg/l (in Maumee Bay)
PO_4 from 105 μg/l to 450 μg/l (in Maumee Bay)

There is some controversy about both the causes and the effects of these changes. Beeton (1961) stated that they are probably of no consequence to the biota and that they must be due to materials in the inflowing water. Curl (1957) calculated that the Maumee River alone carried in over 125 metric tons of phosphates per year; these act as fertilizer for phytoplankton. Verduin (1964) pointed out that since the Federal price-support program limits acreage tilled but not production per acre, farmers in the Maumee basin have been applying large amounts of fertilizer, causing increases in nitrates in the runoff to Lake Erie (he gave collateral evidence for this by the increase in the number and prosperity of fertilizer dealers in Bowling Green, Ohio during the previous 15 years). Harlow (1966) found that in the Michigan area of the lake, municipal wastes contributed 90 per cent of the nutrients, with land drainage a minor factor. On the other hand, Kramer (1961) stated that much of the increased concentration of soluble salts in the lake appears to be due to loss of water through evaporation (a component of natural lake aging). Assuming all concentration of salts to be attributed to evaporation, he derived an evaporation rate of 2.3×10^{-6} cubic meters per second, well within the range of other reported results. Ownbey and Kee (1967) reported that the Detroit and Grand Rivers together contributed 90 per cent of Lake Erie's chloride input. It seems that the true cause of the chemical changes must involve both evaporation and inflow and that they must have some effect on the phytoplankton if not on other biota.

DISSOLVED OXYGEN

Perhaps the most serious environmental change in Lake Erie has been in the dissolved oxygen levels at the bottom. Regardless of the average dissolved oxygen concentration in a body of water, a single instance of anaerobic conditions or levels below the lethal limit will kill all the benthic organisms and have many far-reaching consequences, lasting until new populations have been established by immigration. Such conditions are usually associated with thermal stratification over a bottom high in organic matter. The three basins of Lake Erie differ in these respects. The western basin is high in organic matter but is too shallow to stratify, the eastern basin stratifies but is low (although increasing; Carr, 1962) in organic matter, while the central basin stratifies and has accumulated sufficient organic matter to cause oxygen depletion to become the usual summer condition in recent years.

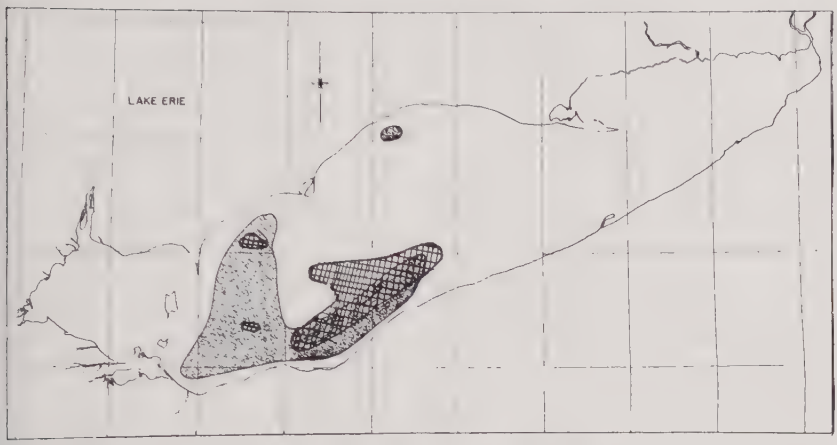

Figure 2. Areas of Lake Erie with less than 1 ppm dissolved oxygen during the synoptic surveys of 1959 and 1960: hatched area, September 1-4, 1959; stippled area, August 30-31, 1960. (From Carr, 1962)

Low levels of dissolved oxygen have been observed in the central basin several times since 1930 (Beeton, 1961) and might have been more commonly detected with better sampling and analysis. Depletion has become gradually more extensive over the past three decades. At present over 70 per cent of the central basin (more than 415,000 hectares or about 1,600 square miles) has less than 1 ppm dissolved oxygen at the bottom from mid-July through September (Figure 2). The oxygen demand of the water in the hypolimnion is not great enough to cause this depletion, but the sediments themselves have a high chemical oxygen demand (Carr *et al.*, 1963). Thomas (1963) calculated the oxygen deficit rate for the central basin by determining the difference in dissolved oxygen in the hypolimnion on two dates at least a month apart. The 1929 rate was 0.0065 milligrams per cubic centimeter per day. In 1959 and 1960 rates were 0.03 and 0.037 milligrams per cubic centimeter per day, respectively. This indicates an increase of 5.7 times in productivity, which uses over 70 per cent of the hypolimnial oxygen by late August. The limiting rate for aerobic conditions to be maintained is only slightly higher, i.e., 0.04 milligrams per cubic centimeter per day.

Oxygen depletion in the western basin occurs only when thermal stratification is set up by long, warm, windless periods. Bottom productivity is so high, however, that only 5 days of stratification are now required for the dissolved oxygen to drop below 3 ppm, whereas 28 days were required in 1953 (Carr *et al.*, 1965; Beeton, 1966). The results of such an occurrence are discussed under the following topics in relation to invertebrates.

PHYTOPLANKTON AND OTHER ALGAE

It is difficult to draw conclusions regarding changes in the algal flora of Lake Erie because of insufficient studies and a large amount of seasonal variation. However, the total abundance of phytoplankton has increased almost threefold, and some shifts in dominant species have been documented (Beeton, 1966). Burkholder (1929) found "clean-water" diatoms, especially *Tabellaria* and *Asterionella*, abundant in samples taken in 1928. Chandler (1942) found that diatoms composed 98 per cent of the spring pulse and 77 per cent of the winter pulse in 1939-40. Davis (1961) found diatoms still dominant in all seasons in 1950-51, but by 1956-57 his collections showed green algae clearly dominating the autumn phytoplankton. Even within the diatom group, changes have occurred. Verduin (1964) listed the dominant western basin ditoms before 1950 as *Asterionella formosa, Tabellaria fenestrata* and *Melosira ambigua;* by 1960-61 these had been replaced by *Fragilaria capucina, Coscinodiscus radiatus* and *Melosira binderama.* Davis (1964, 1966b) observed a similar shift in the central basin on the basis of records from the Cleveland water intake. Analysis of these records from 1919 to 1963 showed that there had been a consistent increase in the average quantity of phytolankton. The vernal and autumnal phytoplankton maxima had consistently become more intensive and had lasted longer. The periods of minimum phytoplankton in winter and summer had become shorter and less well marked, until the winter minimum failed to develop at all in some of the latest years. Davis also observed that blue-green and green algae had partially displaced the diatoms in autumnal pulses, and Casper (1965) observed a bloom of blue-green algae covering 206,500 hectares (about 800 square miles) of the western basin for two days in September 1964. This bloom was composed of *Anacystis, Oscillatoria, Carteria, Aphanizomenon* and *Anabaena.* It is generally agreed that these genera are good indicators of eutrophy, and they are now among the dominants in Lake Erie (Beeton, 1965).

Attached and floating algae (mostly filamentous) have also increased. Since the early 1930's complaints have grown of decomposing, malodorous accumulations of *Cladophora* along the shoreline, particularly around the Bass Islands and the eastern basin (Neil and Owen, 1964).

ZOOPLANKTON

The zooplankton of Lake Erie has been only sparsely studied, but some changes can be seen. Wilson (1929) found cladocerans much more abundant than copepods, with *Daphnia pulex* and *Epischura lacustris* the dominant species of the two groups. Bradshaw

(1964) presented evidence from collections at 10-year intervals (1939-1949-1959) for a large increase in cladocerans and a slight increase in copepods over the 20-year period. Davis (1966a) stated that *Daphnia retrocurva* was then the dominant cladoceran, and that the copepod *Diaptomus siciloides*, chracteristically an inhabitant of shallow eutrophic waters, had appeared. The quantitative validity of many of these collections is in doubt, since they were made with the Juday plankton trap, which is selective against the more agile zooplankters.

BENTHIC INVERTEBRATES

The changes in benthic populations in the western and central basins revolve around the naiad of the mayfly *Hexagenia limbata* (Ephemeroptera), a clean-water inhabitant which until 1953 was the dominant benthic organism. Wright and Tidd (1933) found 283 *Hexagenia* per square meter in 1929 and 510 per square meter in 1930. Evidently little change occurred over the next two decades. Chandler found 493 per square meter in 1942 and 351 per square meter in 1943 (Britt, 1955a). In 1951-52, Wood (1963) found 235 per square meter in collections taken through the ice. On September 1-4 in 1953, Britt (1955a) observed an unusual thermal stratification due to hot, calm weather in the western basin and found oxygen concentrations as low as 0.70 ppm near the bottom. Bottom samples collected on September 5 had an average of 465 *Hexagenia* per square meter, all of which were dead. Later in September and again in November, the average number of living nymphs was only 44 per square meter. Examination of the stomach contents of silver chubs (*Hybopsis storerianus*), an important predator on mayfly nymphs, showed a great reduction in the use of *Hexagenia* in September and November of 1953 as compared with that during the same period in 1952. Britt predicted that this short period of stratification would have long-lasting effects on the economy of the western basin; a prediction which has been upheld by later events.

In 1954, Britt (1955b) discovered that a high level of repopulation had occurred, with an average of 827.5 *Hexagenia* per square meter at the same stations he had sampled in 1953. These were all early instars, probably the product of resistant eggs that had survived the low oxygen in 1953. Unfortunately this abundance did not last. In 1957 Beeton (1961) found only 39 per square meter, and in 1961 Carr and Hiltunen (1965) found fewer than 1 per square meter, a decrease of 99 per cent since 1930. In both the western and central basins, the plague of adult mayflies that was characteristic in summer around the lights of south-shore cities has been absent since 1953 (Verduin, 1964; Davis, 1966b). Caddisflies (Trichoptera), also formerly abun-

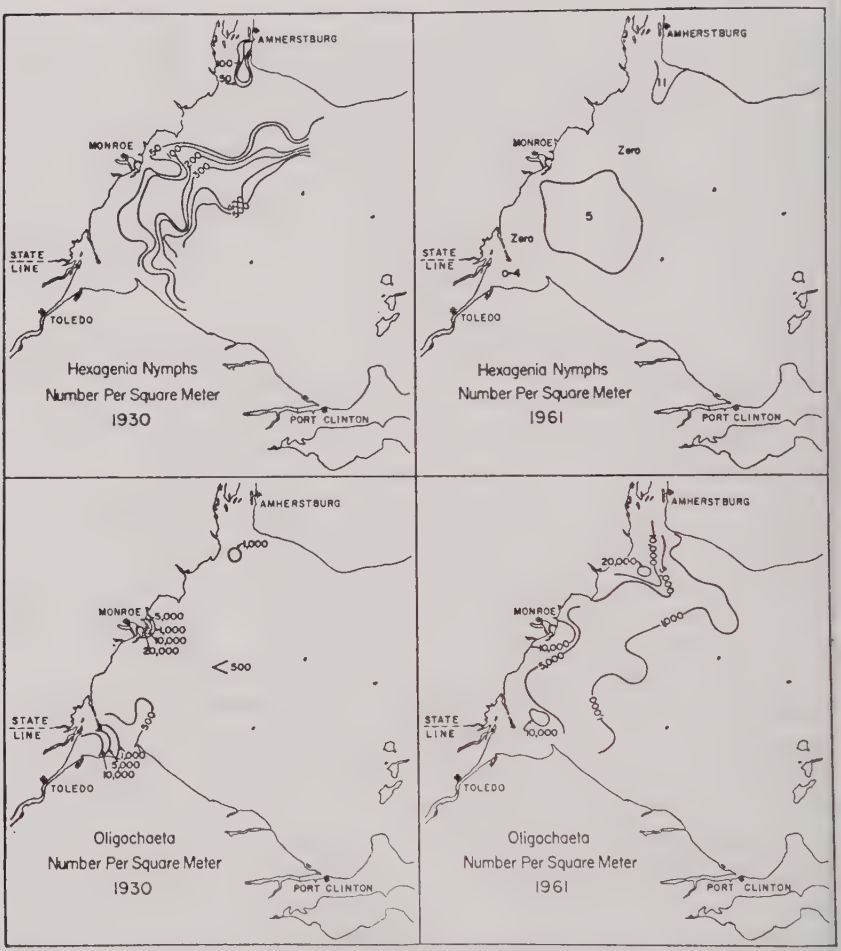

Figure 3. Distribution and abundance of *Hexagenia* nymphs and oligochaetes in western Lake Erie in 1930 and 1961. (From Beeton, 1965)

dant, had decreased to less than 1 per square meter by 1957 (Beeton, 1961).

As might be expected, other organisms, more tolerant of adverse conditions, appeared to occupy the niche left by the mayflies and caddisflies (Figure 3). Oligochaete worms (mostly Tubificidae or "sludgeworms"), which had occurred at a density of about 12 per square meter in 1929, had already increased to 551 per square meter by 1957 and averaged over 2,000 per square meter in 1961 in the western basin, with individual collections ranging up to 39,164 per square meter (Beeton, 1959; Carr and Hiltunen, 1963). This group also increased in the central basin, although all organisms except

nematodes have decreased greatly there in the last few years due to the anaerobic conditions (Beeton, 1961). Chironomidae (Diptera) larvae increased from 56 per square meter in 1930 to 119 per square meter in 1951-52, 299 per square meter in 1957, and 355 per square meter in 1961 (Beeton, 1959, 1961; Wood, 1963; Carr and Hiltunen, 1965). In addition, fingernail clams (Sphaeriidae), sewage fungus (*Sporophilus*) and sulfur bacteria have increased or appeared recently in the central basin (Langlois, 1964). Carr and Hiltunen (1965) summarized the changes in the western basin in the preceding 31 years as follows: a 9-fold increase in Oligochaeta, 4-fold increase in Chironomidae, 2-fold increase in Sphaeriidae, 6-fold increase in Gastropoda (snails), 400-fold decrease in *Hexagenia* and an increase in the area of heavy pollution from 263 to 1,020 square kilometers. Obviously, not all of these changes are the result of the catastrophic oxygen depletion of 1953 (Beeton and Chandler, 1962), but such conditions certainly accelerated the process. Davis (1966b) stated that similar changes in fauna, although less extreme in numbers, have occurred in the central basin. Little is known of the extent of change in the eastern basin benthos.

FISHERIES

Nearly all the available data on changes in the fish fauna of Lake Erie stem from the commercial catch. Naturally, such data may not show important changes in species which are not commercially profitable, but much information has been gathered on those which are. Five main hypotheses to explain the decline and extinction of the most valuable Lake Erie species have been proposed and advocated by various schools of thought: (1) high temperature, (2) oxygen depletion in the central basin, (3) overfishing, (4) pollution and (5) new predators or competitors. All of these are interrelated and probably mutually responsible in various degrees (Regier, 1966). The most desirable species have, in succession, undergone rapid population declines from which they have not permanently recovered. Since the proposed causes for these crashes are in most cases similar, it may be simplest to examine the history of each population and then the controversy over causes.

The first species to decline was the lake herring cisco (*Coregonus artedi*), which began to be exploited in the 1880's, fluctuated, exhibited a large yield in 1923 and 1924, suddenly collapsed in 1925, stayed minimal for 20 years, exhibited a large yield in 1945 and 1946, and again crashed, staying minimal to the present (Van Oosten, 1930; International Board of Inquiry for the Great Lakes Fisheries, 1943; Dymond, 1964). This collapse, being the first of lakewide importance, stimulated much concern among fishermen and public

officials, who were inclined to suspect pollution and other factors, rather than overfishing, as the cause. Three studies were initiated: one by Fish (1929, 1960), one by Van Oosten (1930) and one by Wright and Tidd (1933). The first two came to the conclusion that overfishing was at fault, and all three agreed that pollution was not the cause. Van Oosten determined that most of the ciscos present in 1923 and 1924 were concentrated in a small area of the central basin, probably because of adverse conditions elsewhere, and thus were easily "cleaned out" by the fishermen, accounting for the heavy yield followed by collapse.

The whitefish (*Coregonus clupeaformis*) fishery in the western basin greatly decreased about 1890 and practically vanished about 1920 (International Board of Inquiry for the Great Lakes Fisheries, 1943). It remained productive in the rest of the lake until about 1954 (Chandler, 1964). The sauger (*Stizostedion canadense*) fishery, which was generally a secondary one, declined about 1946 (Chandler, 1964).

The populations of walleye (*Stizostedion vitreum vitreum*) and the so-called "blue pike" (*Stizostedion vitreum glaucum*) seem to have some inverse correlation in abundance (Figure 4). The blue pike seem to have been restricted to the colder waters of the lake (Doan, 1942) and were probably placed at some disadvantage as these waters become smaller and less habitable. After exhibiting several large fluctuations, the catch declined from 8,550,000 kilograms in 1956 to about 226 kilograms in 1958 and later years (Powers and Robertson, 1966). Reflecting this decline, the growth rate of the remaining blue pike increased eightfold between 1951 and 1959, but the few pike caught in 1963 were mostly over 10 years old, inspiring little hope for recovery of the population (Beeton, 1965, 1966).

The walleye fishery showed an upward trend in production from 1929 to 1956 (910,000 to 7,100,000 kilograms) but declined rapidly after 1960, producing only 325,000 kilograms in 1965 (Wolfert, 1963) and now is fluctuating. The growth rate of the remaining population has increased markedly since its collapse, as has that of the blue pike (Beeton, 1966).

Another species which has disappeared from the commercial catch is the lake sturgeon (*Acipenser fulvescens*). These were mostly removed at an early date because of their abiltiy to wreck fish nets, and were destroyed or used as fuel or fertilizer until their value as food was realized (Langlois, 1945), by which time, however, their numbers were severely reduced.

As the commercially important species have declined, other, less-desirable species have increased. The exotics such as gizzard shad

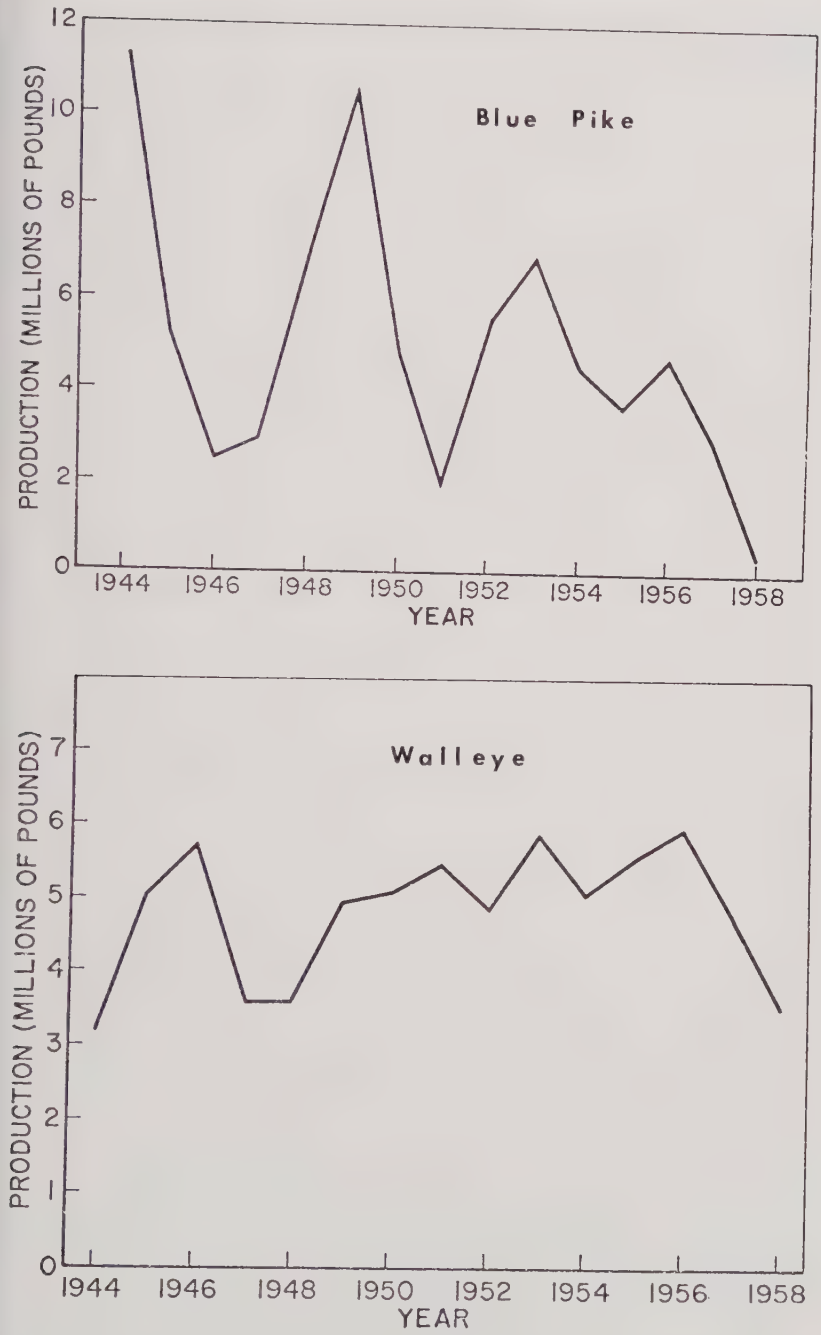

Figure 4. Annual catch of blue pike and walleye from Ohio waters of Lake Erie. (From Brouillard, 1963)

(*Dorosoma cepedianum*), alewife (*Alosa pseudoharengus*), white bass (*Roccus chrysops*) and smelt (*Osmerus mordax*) have become common, and native "rough fish" such as carp (*Cyprinus carpio*) and sheepshead or freshwater drum (*Aplodinotus grunniens*) have increased in numbers and percentage of the catch (Mills, 1953). The yellow perch (*Perca flavescens*) has to a large extent replaced the higher valued species (Figure 5) in the fishery, but its lower unit price causes the net income to be much lower than previously, and thus the number of fishermen has decreased (Brouillard, 1963).

The total catch of all species in Lake Erie has remained remarkably constant for many years because of the replacement of high-priced stocks with rough fish as the former have declined. It was 26,300,000 kilograms per year about 1925 (Fish, 1929), over 11,370,000 kilograms per year about 1944 (Langlois, 1945), and 22,700,000 kilograms per year recently (Beeton, 1965). The fishing industry, however, has been hard hit by the species change because of its ultra-conservative attitudes, especially its reluctance to develop uses and markets for the newly abundant but unexploited species, and by the hodgepodge of regulations imposed by two federal and five state and provincial governments which have so far been unable to agree on uniform policies (Greeley, 1961; Anonymous, 1963; Dymond, 1964; Frick, 1965).

The opinions as to the cause of the decline of major species have been centered around two camps, that of Van Oosten and that of Langlois. Van Oosten (1930, 1948, 1949) held that overfishing in the biological sense (i.e., to the point where the stocks could not easily regain their former abundance) had definitely occurred in the case of the cisco and was a more likely explanation for the decline of the other species than the environmental factors blamed by the Langlois group. In this, Van Oosten has been supported to some extent by others (Fish, 1929; International Board of Inquiry for the Great Lakes Fisheries, 1943; Mills, 1953; Regier, 1966). Regier *et al.* (1968) in a recent extensive review, concluded that overfishing and poor management were largely responsible for the decline of the walleye population in the western end of the lake. Van Oosten and his followers do not deride the importance of environmental factors, but seem to view them as setting the stage for overfishing. He also mentioned disease, parasites and competition as possible negative factors. Regier (1966) pointed out that the more limiting the Lake Erie environment is, the more readily overfishing can occur.

Langlois and his supporters (Langlois, 1945, 1954, 1964; Doan, 1942; Galtsoff *et al.*, 1954; Dymond, 1964) have held that environmental factors, particularly turbidity, related siltation on spawning

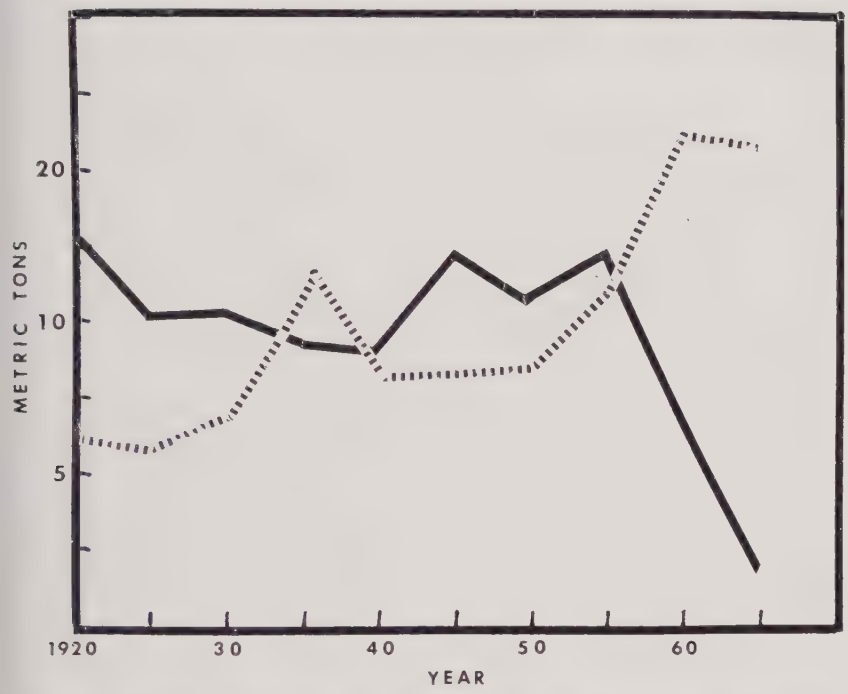

Figure 5. Annual commercial catch in Lake Erie from 1920 to 1965 by groups of species. Solid line: sturgeon, cisco, whitefish, walleye and blue pike; broken line: smelt; carp, goldfish, suckers, catfish, bullheads, burbot, white bass, yellow perch and sheepshead (low priced species).

and nursery ("key") areas, and temperature, are the controlling influence on the level of fish abundance in the lake and act essentially independently of fishing pressure. They also believe that stocking has been largely useless for the same reason (Dymond, 1957). Recently Lawler (1965) concluded that temperature, in the form of the general warming trend, is largely responsible for the decline of the whitefish population which is at the southern limits of its range in Lake Erie.

FUTURE PROSPECTS

It is generally agreed that the hope for salvation of the fisheries and ecology of Lake Erie lies either in a return of the high-priced species through rehabilitation of the environment coupled with stocking, an increase in demand or price for remaining species, or introduction of new, desirable exotics (Frick, 1965; Great Lakes Fishery Commission, 1965). Rehabilitation of the environment seems almost impossible but is probably the approach most likely to be clamored for by the public and attempted by government agencies.

Langlois (1964) has proposed several remedial actions for the lake environment, all within the realm of feasibility from an engineering standpoint if not from a practical one. (Many already-completed government resource-management projects seem to have this type of feasibility.) These include (1) transferring sludge from shoal areas to low shorelines to lower the oxygen demand of the bottom and provide spawning beds; (2) aeration of the bottom waters by compressed-air hoses; (3) opening of the pre-glacial outlet of the lake west of the Welland Canal and installation of gates to permit periodic drawdown for aerating the bottom, controlling floods and facilitating levee construction; (4) a levee across the island region to carry a highway and permit drainage of the western basin for agricultural use, with only the ship channels maintained; and (5) alternate boat routes through channels dug north of the lake. Anderson (1966) has proposed a scheme for recirculating water from Lake Ontario to Georgian Bay and back through Lakes Huron and Erie for reuse in various ways. The potential effects of this and other schemes on the ecology of the lake are difficult to predict, but it is relatively certain that if changes of some sort are not made in man's use and misuse of the Lake Erie resource, he will lose it entirely.

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WILD TURKEY STUDIES IN NEW YORK BY RADIO-TELEMETRY[1]

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ABSTRACT

A 26MC/S radio-telemetry system adequate for locating wild turkeys at distances up to 2 miles was assembled. One mile was accepted as the average range of the system and accuracy was established as within $\pm$ 15.8° ($P = 0.05$) of a determined radio-bearing. Calculated life of transmitting units was not realized in any of 11 instances.

Eleven wild turkeys were equipped with transmitters and tracked during the spring in 1965 and 1966. Tracking was carried out on three areas. Two strains of turkeys were involved, wild-trapped birds transferred from southwestern New York and resident birds that derived from plantings of game farm stock. Transferred wild birds were tracked over relatively large areas, whereas those of game farm origin were notably sedentary and exhibited other behavior considered atypical of the native eastern wild turkey.

This project was initiated: (1) to develop a radio-telemetry system for use under New York State conditions; and (2) to use the system to collect data on wild turkey movements and, time permitting, on the reproduction, nesting and brood-rearing behavior of wild turkeys.

In colonial and pre-colonial times the eastern wild turkey (*Meleagris gallopavo silvestris*) was reported as common in several New York State locations south of the Adirondack region (DeKay, 1844; Eaton, 1909; Wright, 1914, 1915). Nevertheless, sometime shortly after 1844 the wild turkey was extirpated from the State (Eaton, 1909). Several explanations have been advanced to account for this disappearance, all related directly or indirectly to settling and agricultural development.

The advance of agriculture and the resulting changes in land use drastically reduced and altered the extensive forests which figure so largely in eastern wild turkey habitat. This was undoubtedly the most important cause of extirpation and definitely the most lasting in effect. Also important was increased human activity, i.e., more hunting and disturbance throughout the year, due to a nearly uniform distribution

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[1] This study was made under the auspices of the New York Cooperative Wildlife Research Unit which is jointly supported by the U. S. Bureau of Sport Fisheries and Wildlife, Cornell University, the New York State Conservation Department and the Wildlife Management Institute. The paper is derived from a Master's thesis submitted to the Graduate School at Cornell University in 1967. Grateful appreciation is given to Drs. Oliver H. Hewitt, Daniel Q. Thompson and W. C. Dilger. James Ashe of Freeville, New York, designed and constructed most of the telemetry equipment used in the study. John J. Whalen, regional game manager of the New York State Conservation Department, provided all facilities needed for field work carried out during 1966.

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of the rural population (Ellis *et al.*, 1957). Diseases introduced by domestic poultry, especially blackhead, have also been frequently mentioned. The relative importance of the factors no doubt varied from one locality to another but the result was unmistakable, the loss of the wild turkey from the State's fauna.

Changing economic conditions since the mid-1800's have dictated agricultural abandonment of much "marginal" land, predominantly in the more rugged and less fertile sections of the State. In these areas plant succession has transformed open fields to woodland, the rural population has decreased, and modern poultry technology has reduced the number of free-ranging poultry flocks. An environment suitable for the wild turkey has gradually been, and is continuing to be, restored. Bump (1940) mentioned four attempted reintroductions of wild turkeys into New York during this period; all were failures. First reports of wild turkeys seen in New York in recent years came from along the Pennsylvania border in the southwestern part of the State during the late 1940's, a result of a natural range extension by turkeys from Pennsylvania (Eaton, 1964).

In an attempt to accelerate the spread of the newly returned species to all suitable coverts in its former range, a propagation and stocking program was carried out by the State Conservation Department from 1952 to 1959. A total of 3,176 turkeys were released in 22 of the State's 63 counties (Mason, 1964). Stocking of game farm birds was discontinued after 1959 in favor of trapping and transferring birds from established wild flocks. Since 1959, the trap and transfer program has resulted in approximately 50 birds being moved annually (Austin, 1964a).

As a result of the natural spread into the southwestern counties and subsequent liberation of game farm stock over most of the southern half of the State, two more or less distinct strains of wild turkey are present today. Western New York populations, primarily in Game Management Regions 2 and 3, are progeny of birds that emigrated from Pennsylvania and of game farm-reared birds. Populations in eastern New York, largely in Region 7, are progency of game farm-reared birds only. An estimated 3,500 to 4,000 wild turkeys are present in Region 2 (Austin, 1962; Eaton, 1964), while only 250 to 300 are believed to be present in Region 7 (John J. Whalen, personal communication). Limited hunting seasons have been held in both areas since 1959 and 1963, respectively. The estimated legal kill in Region 2 was between 150 and 300 annually for the four hunting seasons 1959 through 1962 (Hyde, 1960; Mason, 1964). Statistical estimation based on the Department's game take survey placed the legal kill between 1,018 and 1,274 for the 1963 and 1964 seasons in this area (Austin,

1964b, 1966). The legal kill in Region 7 was 56 in 1963, 31 in 1964, and 12 in 1965 (Austin, 1964b, 1966; and John J. Whalen, personal communication).

Using Knoder's (1959) classification system, turkeys in Regions 2 and 3 would be classified as feral (Eaton, 1964; and Frederick M. Evans, personal communication). All birds in Region 7 would be regarded as semi-feral and domestic. In addition to this difference in habit, and to a degree in habitat, other differences are believed to exist. In the eastern area, the adult-juvenile ratio calculated from the hunting season kill has been consistently higher than that in the western area (Austin, 1964b, 1966), and dispersal into suitable habitat surrounding established flocks has not taken place to the degree anticipated.

The detailed information needed to explain and critically evaluate these suspected differences in performance of the two strains, and on which to formulate sound management objectives and methods, was not available. The secretive nature and protective coloration of the eastern wild turkey combine with dense woodland habitat to make observation and study difficult. Past experience indicated that the necessary information could not be accumulated in a reasonable time by methods previously used. Solicited landowner reports, mail surveys (Austin, 1964a; Brown, 1958a, 1958b), and limited observation by Conservation Department personnel were methods used to provide population information prior to 1964. Even with increased emphasis on these methods, it was doubtful if information could be efficiently obtained because of the difficulties in consistently locating specific birds and maintaining contact with them for extended periods. An observation or tracking technique was required that would permit locating and maintaining contact with specific birds whenever desired, under all field conditions, with high reliability, and minimum disturbance.

The application of radio-telemetry to field investigations with similar locating and tracking problems had been successful attempted as early as 1959 (LeMunyan *et al.*), and further improvement and development of both equipment and technique were subsequently reported by several investigators (Cochran and Lord, 1963; Marshall and Kupa, 1963; Southern, 1963; Verts, 1963). Bolstered by the success of these workers, it was decided to use radio-telemetry to gather information on wild turkey movement, productivity and behavior.

EQUIPMENT AND METHODS

In most general terms, a radio-telemetry system consists of a transmitter and a receiver. The transmitter is placed on an animal to be

studied and the investigator, using the receiver, picks up the transmitter's signal. Using a directional antenna coupled to the receiver, he obtains a bearing on the transmitter, then moves to another known location, repeats the direction-finding procedure, and by plotting the intersecting bearings locates the transmitter and, hence, the animal.

Equipment Used

Selection of a telemetry system is a balance between available resources and the requirements of the particular study. In this study, money, time and the species under investigation made up the essential resources. Such factors as the locale of study, information desired and biological considerations of the species (i.e., size and mobility) dictated the major requirements.

In the present study, time and money were limited; therefore, it was desirable and necessary to use existing equipment designs as much as feasible. In addition, the system was to be adaptable enough that it could be used virtually anywhere in the State without major changes. This called for a receiver mounted in a vehicle providing ready mobility via existing road systems so that there would usually be only a moderate distance between the transmiter and receiver.

The physiography of the areas in New York now occupied by wild turkeys is generally rolling to very rough, primarily forested or abandoned land in various stages of reversion, with only fair road systems at best. This fact, coupled with the mobility of the wild turkey and the desire to be able to locate marked birds at any time with minimum disturbance to the bird, dictated a telemetry system not adversely affected by rough topography, with a range of at least 1 mile, in order to reliably make contact with marked turkeys under the most difficult circumstances anticipated.

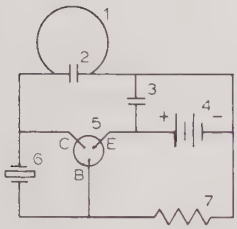
A system similar to those described by Cochran and Lord (1963) and Southern (1963) was selected. The 26-megacycle band (26.550 to 26.650 megacycles per second (Mc/s)) was chosen as the frequency of operation because of the availability of components, moderate effect of topography on reception range, relative ease of transmitter construction and the recommendations of other workers. Preliminary work indicated that a 1-mile range could be realized with a transmitter on this frequency drawing between 1.5 and 2.0 milliamperes (ma) of current at 2.7 volts (v).

To produce the least effect on the behavior of the turkey carrying it, and its flock-mates, the radio transmitter has to be small, light and unobtrusive, yet large and heavy enough to carry a power supply sufficient for 150 to 200 days of continuous operation. This long life

requirement was a direct result of the disparity between the trapping period, primarily February and March, and the beginning and duration of the reproductive and brood-rearing seasons, April through August. To meet this life requirement of 150 to 200 days, a transmitter drawing 1.5 to 2.0 milliamperes of current would require a power supply with 7,200 milliampere-hours (mah) of available current. Four Mallory RM12-R mercury cells, two in parallel × two in series, were chosen to provide the necessary 2.7 volts and 7,200 milliampere-hours. The weight of this power supply was 166 grams.

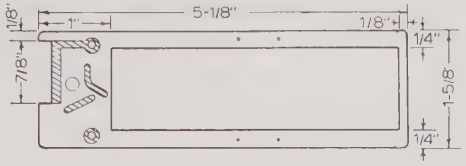
A juvenile male and a juvenile female wild turkey, wild-trapped progeny of game farm-reared stock, were used in tests to determine a suitable transmitter configuration and placement and to develop a harness, as well as to observe the effects of carrying a transmitter on normal behavior. A flat board with a loop antenna attached near one end, perpendicular to the length and width of the board, was selected as the transmitter configuration. The rigidity of the board maintained the critical distance between the poles of the antenna and provided a durable base on which to mount the components and power supply. The board rested on the bird's back in the interscapular region, with the loop antenna encircling the neck. It was harnessed to a bird by attaching two ½ x 10-inch strips of "Saflag" material to two small wire anchors near the lower center of the antenna, passing them under the wings and fastening them to similar anchors on the edges of the battery board. Fastening was done with several wire staples; excess material was cut off. It was important that the straps originate near the lower center of the antenna and be drawn up snugly to prevent a bird from slipping its head and neck out of the encircling antenna. Attachment in this fashion minimized the effect of transmitter weight by positioning it above the bird's center of gravity; the method of harnessing allowed for individual fit.

A weight unit with the size and shape of the proposed transmitter was tried on the captive 9.5-pound hen turkey to assess its effect on behavior. A total weight of 236 grams (40 grams more than a transmitter) was attached, as described, and left in place for 10 days. Compared with the penned tom, the hen was slightly hyperatctive for the first few days; thereafter, her activity decreased somewhat. No startling changes were observed at any time; nor was feather or skin abrasion noted on removal of the test unit. Following this brief test, actual transmitters weighing approximately 196 grams were placed on both birds for a period of about a month with no significant behavioral change; both could run and take wing apparently as well as without the additional weight. From a distance, only a slight feather displacement betrayed the transmitters' presence.

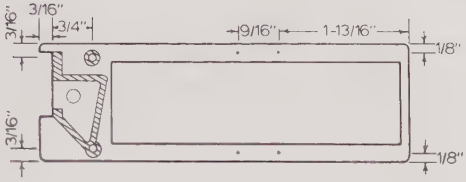


TRANSMITTER SCHEMATIC

1. LOOP ANTENNA
2. CAPACITOR (VARIABLE)
3. CAPACITOR (FIXED)
4. BATTERY (27 VDC)
5. TRANSISTOR (PHILCO T2399)
6. CRYSTAL
7. RESISTOR (VARIABLE)



TOP VIEW



BOTTOM VIEW

PRINTED CIRCUIT BOARD DIAGRAM

Figure 1. Transmitter schematic (after Southern, 1963) and diagram of printed circuit board.

Printed circuit technique was used in constructing the transmitters used in this study to provide maximum strength and durability with minimum weight. Required circuitry (Figure 1) was etched on one end of a piece of copperclad epoxy board 1⅝ inches by 5⅛ inches by 1/16 inch in size. A large rectangle of material was removed from the remainder of the board, leaving a frame as the battery-mounting structure.

Tests with two captive birds demonstrated the need for a resilient antenna that would return to its original shape after being deformed, or one that would not deform. Any marked change in antenna shape would require a change in antenna-tuning to maintain peak operating efficiency. No provision could be made for such tuning; hence, the anteenna could not be subject to permanent deformation. As the first alternative proved much lighter and less restrictive, stainless steel, ⅜ inch wide by 0.010 inch thick, was used for the antenna. Two lengths, 14 inches for hens and 15½ inches for toms, were used to allow a degree of individual fit in the fixed-size loop. Final loop circumferences were 15⅜ inches and 16⅞ inches, respectively, because of the 1⅜ inch distance between antenna poles.

Selection and matching of transmitter components followed the procedures of Southern (1963) and Verts (1963) except that tuning capacitance was selected with a variable capacitor, measured on a capacitance bridge, and fixed-value disc ceramic capacitors were substituted in final construction. If the needed capacitance could not be

duplicated exactly, two capacitors totaling slightly more than required were selected, and the smaller-value capacitor was ground down to give the required total value. No pronounced change in current or audible signal strength was noticed when a completed transmitter was slipped over a person's arm or leg to simulate the effect of the bird on the transmitter's tuning.

After all components were selected and soldered to the printed circuit board, the mercury cells were connected and held in place with epoxy glue at their points of contact with the board. Successive thin coats of clear marine liquid fiberglass sufficient to build up a 0.05-inch coating were applied for encapsulation. In finished form, the transmitters were 1⅝ inches by 5⅛ inches by ¾ inch in size, weighted between 196 and 210 grams, emitted constant signals on discrete frequencies for identification of individual birds, had input powers ranging between 3 and 6 milliwatts and had power supplies for 150 to 200 days of operation.

Although it may be argued that any marking device affects an animal's behavior in some manner, the effect of the transmitter, in spite of its size and weight, appeared minimal. This could be a result of the characteristics of the bird, for Mosby and Handley (1943) stated that a turkey's weight may fluctuate as much as 5 per cent under normal circumstances. The ratio of transmitter to animal weight was approximately 1:27 for the males and 1:18 for the females that were worked with during this study; hence, the additional weight of the transmitter may be no burden at all to a healthy wild turkey. Still, it would be desirable to reduce the size and weight of the transmitter as much as possible in future work to minimize the possibility of behavioral abnormalities.

Expected or calculated transmitter life was not achieved with any of the 11 units used in the study. Suspicion fell upon corrosion of the negative cell terminals, noticed in duplicate units, which could have caused a short and subsequent cell failure. A test to confirm this hypothesis, consisting of six battery packs discharged through resistors, failed to duplicate the corrosion; however, shorter lives than expected were again noted. The results of this test were sent to the Mallory Battery Company, whose representative indicated that the low current drain could cause mercury shorts inside the cells that would result in premature failure. Mallory RM12-W cells, a low-drain version of the RM12-R, were recommended. These cells should be tested for possible incorporation in future work. Also, the arrangement of cells in parallel to attain long life should be avoided to reduce the chance of a bad cell running the battery pack down prematurely.

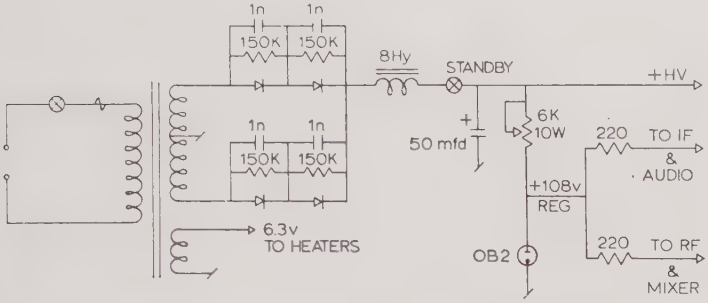


Figure 2. Schematic of power-supply circuitry for 26CM/S telemetry receiver.

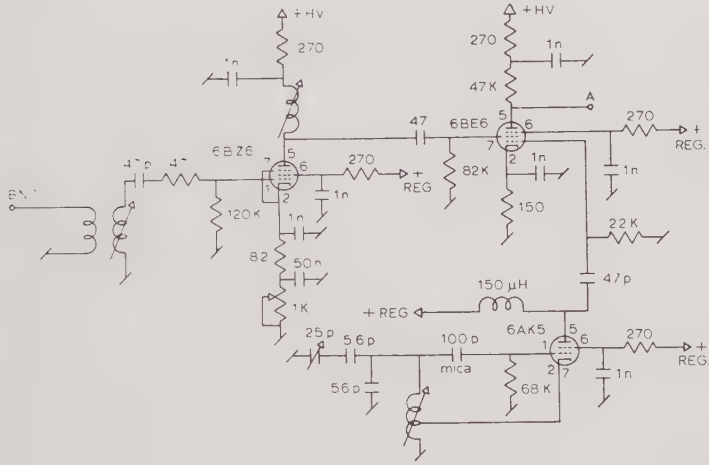


Figure 3. Schematic of mixer circuitry for 26CM/S telemetry receiver.

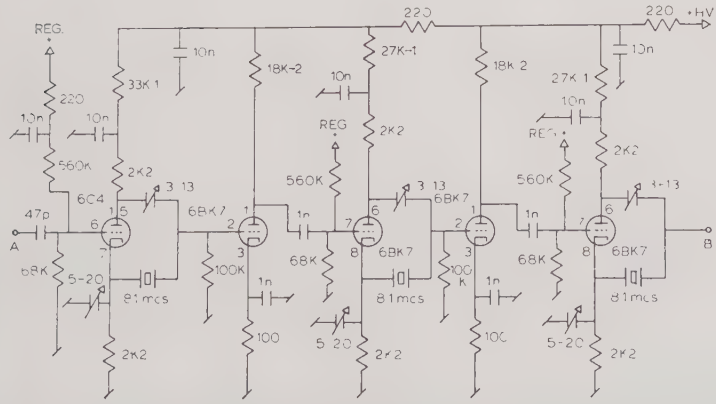


Figure 4. Schematic of intermediate-frequency circuitry for 26MC/S telemetry receiver.

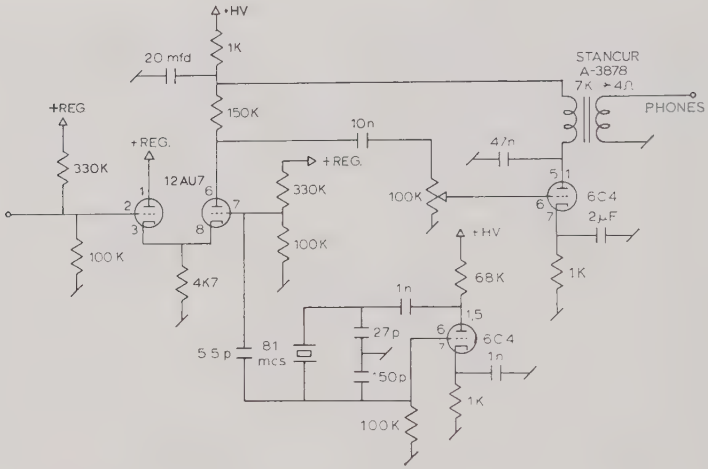


Figure 5. Schematic of detector and audio circuitry for 26MC/S telemetry receiver.

Marine liquid fiberglass did not prove durable enough in thin coatings to provide prolonged encapsulation. Thick coatings were excessively heavy. A soft denture liner and a room-temperature vulcanizing rubber were given limited tests but did not prove promising. The dental acrylic used by Mech *et al.* (1965) appears suitable and should be considered for future work.

The only other criticism of the transmitter was that the harness anchors on the battery board were improperly placed and should be moved about ¾ inch to the rear or bent at a rear-facing angle to reduce harness wear at this point.

A non-crystal-controlled superhetrodyne receiver designed and built by James Ashe was used exclusively during the study. Schematics of the receiver are presented in Figures 2, 3, 4 and 5. As the receiver was not crystal controlled, considerable drift in log readings occurred with changes in receiver temperature. The problem was alleviated by spacing transmitter frequencies at least 10 kilocycles (kc) apart and allowing the receiver to warm up to a near constant temperature before use.

To complete the system, a whip antenna (102 inches long) and power converter (12-volt D. C. to 117-volt A. C.) were installed on a vehicle from which all location work was done. A loop antenna 24 inches in diameter was used to obtain bearings on the transmitters.

Field Methods

To locate a bird, the receiver was coupled to the whip (omnidirectional) antenna, and stops were made at intervals along the

roads of the study area to listen for transmitter signals. Stopping places were selected with past movements of the turkeys in mind or, when the birds could not be located immediately, in a systematic manner around their last known location. When a transmitter's signal was picked up, the loop (directional) antenna was substituted for the whip antenna.

Rotating the loop antenna about a vertical axis resulted in an audible signal change from high to low (null) volume every 180°. The plane of the antenna at either the high or null could be related to the position of the transmitter as both were correlated with the orientation of the antenna in the electromagnetic field of a transmitter's signal. The null of the directional antenna was used for bearing determinations because it was generally narrower and more clearly defined than the high point in signal volume; it was, nevertheless, appreciable in width. To compensate for this, the antenna was rotated back and forth across the null interval until points of equal volume were located to either side. The null was taken as the midpoint of this interval. At least two bearings are needed to locate a transmitter with this system; two angles from positions of known location. In most instances, a third bearing was taken as a check.

Danby Study Area During this phase of the project, the loop antenna was hand held and rotated; bearings were referred to prominent topographic and physical features and then plotted on 7.5-minute U.S.G.S. topographic maps. Rough plotting of bearings was done in the field to select advantageous positions for additional bearings. Usually three bearings were taken on each transmitter to provide one location. Final plotting of locations was done in the office from notes taken during field work.

Although this method of obtaining bearings was crude, checks on the accuracy of the equipment at this time showed that is was very reliable and that the degree of accuracy was sufficient for following the movements of wild turkeys. After considerable experience with the equipment, 1 mile was accepted as the range of the system. Contact was made at up to 2 miles under favorable circumstances. In some situations, it was difficult to make contact at ½ to ¾ mile; however, such situations were extremely rare on this study area.

Bear Spring Mountain and Crumhorn Mountain Study Areas For this second phase of field work, a mount was made for the directional antenna so that more accurate and precise bearings could be taken on transmitter-equipped birds. The antenna was mounted through the roof of a vehicle allowing the operator to rotate it from

Figure 6. Field vehicle with loop (directional) antenna on cab roof and whip (omnidirectional) antenna on rear bumper.

inside while operating the receiver controls (Figure 6). On the inside of the roof, concentric with the shaft of the directional antenna, a 360° protractor was mounted in such a way that it could be rotated independently of the antenna shaft (Figure 7). When a bearing was taken on a transmitter, the protractor was oriented to true north by taking a magnetic compass (Suunto Fast-Accuracy Compass) bearing on the centerline of the vehicle, correcting it for declination and setting the protractor at this reading. After the protractor was aligned, a bearing could be read directly form it when the directional antenna was rotated to the null of a transmitter's signal.

At the start of work at the Crumhorn Mountain area, the null indicator needle (Figure 7) was aligned in the following manner: with the field vehicle and a transmitter at known locations approximately 2,000 feet apart, the protractor was adjusted to true north and the directional antenna was rotated to the null position. The bearing from the vehicle to the transmitter was determined from a map and, with the antenna shaft held fast, the null indicator needle was set at this reading. This procedure was repeated several times with the vehicle in the same location, but facing different directions, with only $\pm 1°$ variations in bearings.

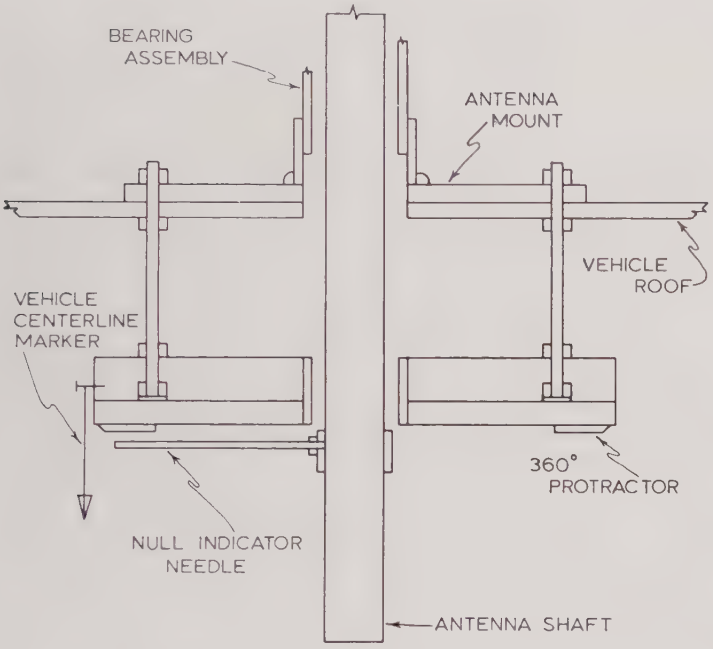


Figure 7. Diagrammatic longitudinal view of compass rose exclusive of antenna bearing assembly.

At each place where a bearing was taken, the vehicle location was recorded in latitude and longitude as determined from U.S.G.S. topographic maps using plastic overlay grids. Only 15-minute-series maps were available for the Bear Spring Mountain area; hence, measurement was made to the nearest five seconds and estimated to the nearest second of angle. Latitude and longitude were measured to the nearest second of angle on the Crumhorn Mountain area for which 7.5-minute-series maps were available.

In addition to a bearing, measurement of the relative activity of each radio-marked bird was made each time a bearing was taken on it. Activity was recorded in one of four subjective categories (not, slightly, moderately, or very active) according to the frequency of change in volume or pitch of the received signal during a 20-second interval. Visual observations of radio-equipped birds while monitoring their signals demonstrated that even very slight movement caused audible changes in a transmitter's signal. Never, even when a bird under observation was standing still, was its signal "not active" for 20 seconds. Experimentation with test transmitters showed that only when an antenna was motionless was a signal steady and, hence, in the "not active" category. Movements causing changes in the shape

or tuning of the transmitter's loop antenna, or in its orientation with respect to the receiving antenna, caused the changes in signal volume.

Once incubation has begun, a hen will spend nearly all of each day on her nest; brief periods of activity occur daily, decreasing, or even ceasing, as incubation advances. This is in sharp contrast to activity in early spring. It was hoped that the activity measurements would be useful in pinpointing the start of incubation by indicating this pronounced change in behavior pattern.

Records of temperature and precipitation were kept for both study areas from mid-April until early June in an attempt to evaluate the effect of weather on nesting success. One recording station was maintained on Bear Spring Mountain (1,760 feet; 42° 06′ 02″, 75° 03′ 05″) while two, one at high elevation (1,760 feet; 42° 31′ 33″, 74° 55′ 43″) and the other at low elevation (1,340 feet 42° 30′ 49″, 74° 55′ 48″), were maintained on Crumhorn Mountain. Each station consisted of a rain gauge (Tru-Chek Rain Gauge, Edwards Manuafcturing Company, Albert Lea, Minnesota) and a 7-day, spring-operated recording thermograph (Bendix Model #594 or Casella/London Model #BSS-3231). Precipitation gauges were checked as often as possible.

Accuracy and Reliability Test

In conjunction with work on the Crumhorn Mountain area, an accuracy and reliability test was conducted on the telemetry system. On several occasions when time permitted, a transmitter was placed at a known location, and bearings were taken from other points of known location, using the described direction-finding procedure. Latitude and longitude of both locations as well as the radio-bearing were recorded for later plotting. After plotting, the difference between the true and the radio-bearing (in degrees) and the calculated perpendicular distance from the radio-bearing to the transmitter's position (in feet) were measured as indicators of error. The distance from the receiver to the transmitter was scaled from a topographic map and recorded to the nearest 50 feet.

A sample of 89 radio-bearings was obtained from 103 attempts on 13 days between March 31 and May 31 in 1967. Failure to detect the test transmitter's signal, or a signal too weak to provide a bearing, were the causes of the 14 unsuccessful attempts. No attempt was made to select a particular type of day on which to make determinations; all environmental conditions encountered during field work were represented in the sample. Likewise, locations from which to take bearings were not chosen with any condition in mind other than that they be accessible to a field vehicle.

TABLE 1. ACCURACY AND RELIABILITY OF RADIO-BEARINGS ACCORDING TO SEVEN DISTANCE CLASSES

Distance class (feet)	Mean distance (feet)	Bearings attempted			Mean error		Mean error (feet)
		Number	Successful		Degree	Standard deviation	
			Number	Per cent			
0– 950	655	5	5	100	−9.8	11.0	124
1,000–1,950	1,512	27	27	100	−0.9	6.9	203
2,000–2,950	2,403	17	17	100	−0.5	17.5	794
3,000–3,950	3,428	17	15	88	0.4	6.7	616
4,000–4,950	4,463	17	15	88	2.3	8.0	822
5,000–5,950	5,571	10	7	70	−1.7	3.0	504
6,000–over	7,133	10	3	30	6.3	8.5	722
Total	xxx	103	89	86	−0.38	15.84	xxx

TABLE 2. ANALYSIS OF VARIANCE OF ACCURACY AND RELIABILITY DATA FOR BEARING DETERMINATIONS IN SEVEN DISTANCE CLASSES

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of *F*
Between	6	719.1	119.0	0.6 n.s.*
Within	83	16,137.9	194.4	
Total	89	16,857.0		

* At 0.05 level of significance.

Bearing determinations were attempted between 300 and 8,000 feet from the receiver and separated into seven distance classes. No bearing attempted, or taken, was excluded from analysis since an unqualified statement of the system's accuracy capabilities was desired. Data from the accuracy test are summarized in Table 1. Table 2 presents the results of an analysis of variance testing the null hypothesis that the rates of error were equal in all distance classes. No significant difference was found between class means; hence, the data were lumped and a confidence interval was set on the general mean (Table 1). On the Crumhorn Mountain study area, the true bearing can be assumed ($P = 0.05$) to lie within $\pm 15.8°$ of a determined radio-bearing using the described telemetry system.

Under actual field conditions, an investigator would have no criterion by which to judge the relative accuracy of a single bearing without further information. But since more than two bearings would usually be taken in any location attempt, a large triangle of closure

would suggest at least one spurious bearing. In such cases, additional bearings could be taken and the suspected bearings eliminated from consideration. This procedure was followed during this study. For this reason the 95 per cent confidence interval of $\pm 15.8°$ is probably maximum for actual working conditions.

While a regulated test to determine the contribution to total error from any source was not run, some factors (i.e., high-voltage transmission lines, topography and vegetation) were critically examined for association with abnormally high levels of error. Ellis (1964), Slade *et. al.* (1965) and Southern (1963) mentioned large errors associated with one or all of these factors.

Several bearings taken near the high-voltage lines at the northern edge of the area did not show large errors regardless of their relative direction. Topographic irregularities, while not of marked extent on the immediate study area, could not be correlated with any change in the rate of error. Likewise, changes in vegetation did not appear to affect the rate of error. The working range of the system was reduced at times by interference from the high-voltage transmission lines and regular power lines or by "blank" spots in the signal's reception pattern apparently caused by irregular topography. Occasionally, citizen's band interference covered an entire segment of the receiver's band, drowning out a transmitter's signal for short periods.

Some error, expressed in the large confidence interval, was undoubtedly introduced by the direction-finding procedure itself. Chance for error in taking a bearing on the field vehicle was small since misalignment of as little as 0.25° was obvious. However, local magnetic irregularities would have resulted in incerased error from incorrect protractor orientation.

The width of the null interval in a few instances, generally at long range, was nearly 180°. Balancing the high points on either side of the null was difficult in these cases, and error may have arisen from this source. Also, when two operators took bearings simultaneously or successively, it was common to have a difference of 1° or 2° in the results. This appeared to be due to variations in the hearing and judgement abilities of the operators. Slight rotational play in the antenna-compass rose assembly amounting to 1° also introduced error.

Altogether, a maximum of about $\pm 3°$ could be accounted for in the direction-finding procedure; no allowance is made in this figure for reading and recording errors. For purposes of this study, the calculated level of error was not excessive. However, in planning future investigations, e.g., habitat preferences or detailed movement studies, careful consideration should be given to the accuracy capabilities of the system as well as its other functional and physical characteristics.

PLAN OF STUDY

The wild turkeys used throughout this study were obtained through cooperation with the State Conservation Department. Accordingly, Department personnel carried out all trapping operations and, where the transfer of birds was involved, selected the liberation sites. The supply of turkeys depended entirely on the success of winter trapping operations.

Arrangements were made to conduct the first phase of the study in the vicinity of Ithaca to reduce problems of transportation and to be close to the technician who built the receiver in case service was required. No turkey trapping was being done in this part of the State (Region 3, Figure 8) although scattered flocks of undetermined status were present. For several years, however, birds from southwestern New York (Region 2) had been moved into suitable coverts within the central region as part of the Conservation Department's wild turkey "trap and transfer" program. Birds transferred under this program during the winter of 1964-65 were used in this phase.

The area selected for releasing the transmitter-equipped turkeys was on forested, state-owned lands near the village of Danby, 9 miles south of Ithaca (Figure 8). Due to an unsuccessful trapping season,

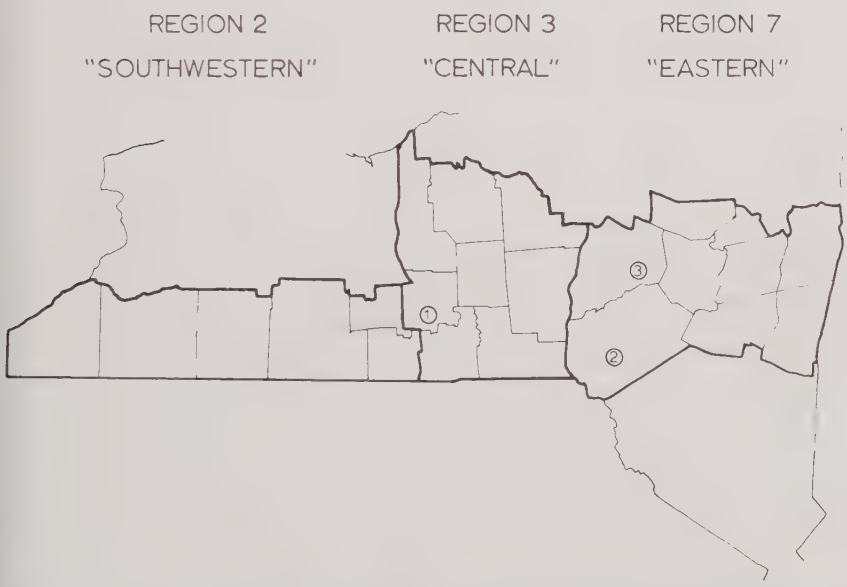


Figure 8. Game management regions of New York where wild turkey populations are present, showing location of (1) Danby, (2) Bear Spring Mountain, and (3) Crumhorn Mountain study areas.

attributed to little snow accumulation, only three juvenile males were transferred and equipped with radio-transmitters. The three toms were trapped on the morning of March 24, 1965, transferred by truck and released late the same night. Since they were trapped in the southwestern part of the state (Allegany County), they are believed to have been from the purest stock available in New York.

Early in 1966, the project was moved to eastern New York (Region 7, Figure 8) to alleviate some of the problems in obtaining turkeys. A wild turkey-trapping program was active there, and several birds had been captured annually since 1959. However, little snow accumulation and an abundance of natural foods hampered trapping in 1966. A flock originally selected for study was abandoned after a futile, month-long attempt to lure the birds to bait. Largely to insure getting all transmitters on birds for the spring tracking season, the decision was made to equip with radios some turkeys from the southwestern area (Region 2) that were to be transferred into the eastern area (Region 7). In this instance, tracking was to determine only whether the birds remained near the release site and whether successful nesting occurred.

Accordingly, six turkeys were released on the Bear Spring Mountain Game Management Area. Three adult toms, one of which carried a transmitter, were released on February 24, 1966 with the thought that any birds transferred later in the spring could be released near the radio-marked tom. On March 31, three adult hens, two of which carried transmitters, were released near the location of this tom.

The remaining available radios were placed on five birds in a flock resident on Crumhorn Mountain. This particular flock was selected because its habits virtually assured capture. In two separate cannon-net shots (March 2 and March 14), 10 of the 12 birds in the flock were captured. One adult male was transferred, and the remaining nine (consisting of five adult hens, one juvenile hen, one hen of unknown age, three adult toms, and one juvenile tom) were released at the trap site. Three hens, captured and equipped with radio transmitters on the first netting attempt, were recaptured on the second without damage to either radios or birds. Two of the remaining three hens captured on the second attempt were equipped with radios. Transmitters were placed only on hens (four adults and a juvenile) so that as much information as possible could be gathered on reproduction, nesting and brood-rearing behavior. In addition to a transmitter, all birds carried one or more wingbands, each with a "Saflag" streamer attached as described by Knowlton *et al.* (1964).

DESCRIPTION OF STUDY AREAS

The three study areas differed in topography and in the degree to which they were forested. They also differed with respect to the human population and land use.

DANBY STUDY AREA

The topography of the Danby study area (Figure 8) is that of a rough water-dissected plain. Elevations range from 1,000 to 1,750 feet with hilltops at nearly equal heights. Small streams and seeps are quite common. Approximately 60 per cent of the area appears as woodland on the 1949 U.S.G.S. topographic maps (7.5-minute series, West Danby and Willseyville quadrangles). Since that time, considerable acreages have been retired from agriculture and left to revert to woodland. At the time of this study, an estimated 10 to 15 per cent of the area was actively used in agriculture. The human population was relatively low and evenly distributed, except in the immediate vicinity of the major highway (Route 96-B) where it was more concentrated. No turkey populations were known to exist in the immediate area when the study began.

BEAR SPRING MOUNTAIN STUDY AREA

The Bear Spring Mountain study area (Figure 8), a State game management area of approximately 7,450 acres, is located 4 miles southeast of Walton in Delaware County. It consists of three north-south-oriented ridges separated from two narrow valleys by long, steep slopes. Elevations range from 1,300 to 2,400 feet. Spring seeps are very common. Except for the valleys which were maintained in a pattern of open fields, food plots, etc., the area was almost completely forested with northern hardwoods and conifer plantations. No human population existed on the area, and population density in the immediate vicinity was extremely low.

Wild turkeys had been released on Bear Spring Mountain beginning in 1953. Between 1953 and 1958, a total of 185 game farm-reared birds were released on the game management area or in the immediate vicinity. In 1965, five birds locally trapped in the eastern region were released. Personnel of Region 7 believe (John J. Whalen, personal communication) that most of the released turkeys moved directly into the lower river valleys to the north and south of the mountain. Small, isolated populations have been reported annually from these areas.

CRUMHORN MOUNTAIN STUDY AREA

The Crumhorn Mountain study area (Figure 8) is located in Otsego Couty 8 miles northeast of Oneonta. Elevations range from

1,300 to 1,900 feet. Spring seeps are infrequent. Situated on a southeast-facing slope and the adjacent flat hilltop, the area was less than 50 per cent wooded at the time of the study. Most nonwooded land was used in low-intensity agriculture for hay and pasture; only a few acres were planted to row crops. The human population was relatively low.

The only liberation of wild turkeys on Crumhorn Mountain had been made in 1962 with 10 birds trapped within the eastern region. Subsequently, the population had been self-maintained but had not increased or dispersed to any extent.

RESULTS

The information obtained by radio-telemetry concerning the behavior of the transmitter-equipped turkeys is summarized and commented upon for each area separately.

Danby Study Area

Unexpected transmitter failures concluded this phase of the study at an early date. Expected lives of the transmitters were 176, 154 and 231 days; actual field lives were 28, 38 and 63 days, respectively.

During the 63-day period, attempts were made to locate the released toms on 35 days; 27 (77 per cent) of these attempts were successful. The movements of the birds as indicated by the distribution of the radio contacts are shown in Figure 9.

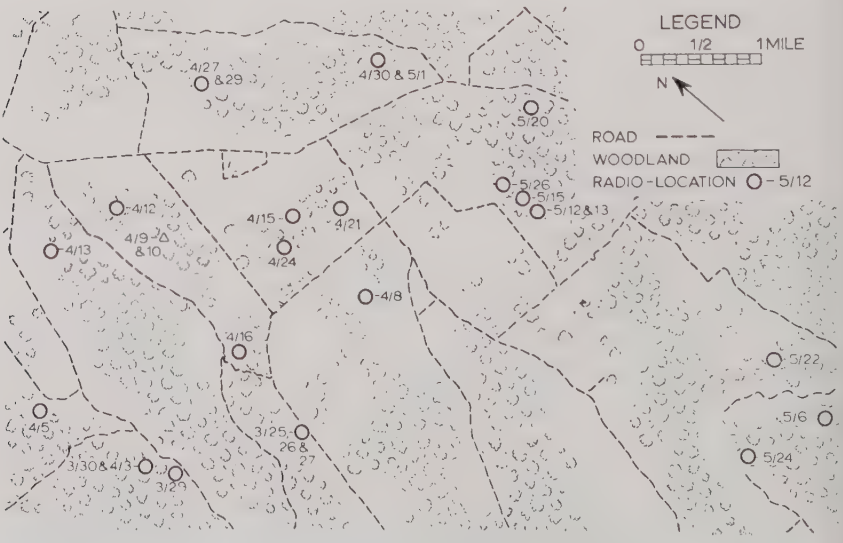


Figure 9. Spring movements of three transferred juvenile male wild turkeys on the Danby study area.

Several factors (e.g., time available, weather and equipment difficulties) prevented locating, or attempting to locate, the birds each day. Despite this, and the premature failure of the transmitters, considerable information was gathered on their movements. The last field evidence of the birds, a series of tracks along an untraveled road, was found five days after they were released. It is doubtful if conventional field methods would have yeilded much information after this date (March 29) as snow suitable for ground tracking was absent after April 3, and radio locations indicated that the birds traveled extensively.

In spite of the evenly distributed rural population, no report of anyone sighting the turkeys was received until the end of the tracking period (May 24-26) when a confirmed report was received from a local farmer. The author first sighted the birds on July 21, 120 days after liberation. There seems no reason to suspect that the three turkeys separated during the tracking period. On the contrary, locations during the first 28 days, when all the transmitters were functioning, showed the three birds together, as did the sighting at the end of May. Therefore, it was assumed that they were together during the entire tracking period, March 24 to May 26.

During this period the birds traversed a rectangular area 3.8 miles northeast-southwest by 6.5 miles northwest-southeast (Figure 9). It appears that the general pattern of movement was to stay in an area for from one to several days, then abruptly move to another area, often a considerable distance away. But the timing of movements, as well as the distance and direction moved, were not regular enough that any definite pattern could be fitted to them. The distances between consecutive locations varied considerably up to a maximum of 4.5 miles, with most in the range of 1 to 2 miles. Three or four days was about the longest time the birds remained in a particular location; in several instances, only one day was spent in an area. No consistent direction of movement was taken between locations, but a gradual movement toward the southeast occured during the course of the tracking period.

Due to limitations in the accuracy of the direction-finding procedure, it was impossible to locate a bird precisely enough for a detailed habitat-use analysis. Yet, it was obvious from the plotted locations that the birds primarily frequented woodlands and isolated field edges. Most of the woodlands used were on rather steep slopes which is not unexpected when the past land use of the area and the habits of the turkey are considered.

An unusually mild spring occurred in 1965; hence, there was no opportunity to follow movements during prolonged severe weather.

During brief periods of inclement weather, the toms were only slightly less active than during mild periods.

Because the birds were not followed continuously throughout each day, it is conceivable (assuming a 1- to 2-mile cruising radius) that many of the locations could be dismissed as random movements from a central roosting site. This may have been the case in a few instances. However, most of the observations were made early in the morning or late in the afternoon and, therefore, represented locations near the roosting site of the previous or following night.

Mobility On three occasions, the birds were followed for an interval during a day. The information from these trackings reveals the remarkable mobility of the wild turkey.

On April 16, the birds were in a hardwood swamp when located at midmorning. An attempt to observe them by walking through the area and using a turkey call failed to turn up even a sign of their presence. When located by radio contact a few hours later, they had left the swamp and moved south along a slope on its eastern side, probably in response to the disturbance. Later in the afternoon, they crossed a stream draining the swamp and proceeded north along the western side of the swamp toward their morning location. During the five hours from first to last location, approximately 1½ miles were covered.

An encouter on April 24 placed their rate of travel at 1 mile per hour for about 2 hours in early afternoon as they moved through an area of secondgrowth hardwoods and isolated fields.

Immediately after sunrise on April 29, the three toms were followed closely in an atempt to make a visual observation. Although no sighting was made, the birds were followed for 4 hours before contact was lost. From all indications, they moved at a leisurely pace covering slightly over 3 miles along a heavily wooded slope. After locating their roosting area late in the evening of April 30, another attempt was made to sight the turkeys on May 1; it failed when a group of deer were jumped and fled toward the turkeys. Contact was lost almost immediately due to a rapid, long movement. In spite of a wide search, contact was not resumed until 5 days later when they were finally located 4.5 miles south of the May 1 location. It is known that the birds moved at least 2 miles from the site of disturbance within the first hour.

Although the distances between consecutive locations were not extraordinary compared with an assumed flock range of 1 to 2 miles based on data reported by Mosby and Handley (1943) and Latham (1956), and the distance from the site of liberation to that of the first visual observation was not exceptionally great (in relation to

the findings of Bailey, 1959), the frequency and distance of movements were nonetheless remarkable. They suggest nomadic wandering after liberation and show a great potential for movement.

Movement After the Radio-tracking Period The farmer who first sighted the released birds indicated that a flock of eight was frequently seen in his fields during the winter of 1964-65. He was certain that the marked toms were not in this group and were not seen until late May when they appeared with a fourth tom that was unmarked. During June and July, several sightings of the four toms were reported by this farmer. In addition, a sighting was reported by another local resident. All sightings were within 1 mile of the May 26 radio-location.

With one exception, sightings took place while the toms were feeding and loafing along an edge between a woodland and an oat-hay field complex. In August, an attempt was made to recapture the marked toms and recover the radio-transmitters for examination. A cannon-net was set up at a prebaited site on this field edge, but a shot resulted only in the capture of two hens that had been associating with the toms since the end of July.

After August, only occasional checks of the area were made. A deer hunter reported seeing at least two of the marked toms within ¼ mile of the field edge in mid-November. They were not sighted in the fields again until early winter when they began to appear frequently. In late December, a roosting site was located in the woods adjacent to the cannon-net site. The roost tree was a beech about 40 feet tall with clean bole to 25 feet. A flock of seven or eight birds, including at least three toms, was ground tracked for 6 hours after leaving this roost one morning. They scratched extensively while moving south about 1 mile before tracking was discontinued.

It is the author's interpretation that the released toms traveled extensively until they met with the existing flock near the end of the radio-tracking period. After that they seem to have confined their movements to the range of this flock. From the standpoint of available wild turkey habitat, this spot was among the best existing in the area. However, it did not appear to be significantly different from the area surrounding the release site. Therefore, an important motivation for movement may have been the urge to locate more of their kind (as described by Mosby and Handley, 1943), as well as settle in a suitable habitat.

Bear Spring Mountain Study Area

The Bear Spring Mountain area was visited every week or 10 days to follow the major movements of the radio-carrying birds.

Twelve location attempts were made during the period February 24 to May 5, eleven (92 per cent) of which were successful in locating at least one of the three birds. The tom released on February 24 was tracked during the following 50 days; one of the two hens released on March 31 was tracked for 14 days and the other for 36 days. Since the transmitters were placed in operation in early February, their actual lives were somewhat longer than the tracking periods. Expected lives were 176, 167 and 150 days, while actual lives were 83, 61 and 61 days respectively. No correlation with expected life was evident.

The activity measurements had little value for their intended purpose, due to small sample size (only 24 measurements for both hens) and early failure of both radios. Similarly, temperature and precipitation records had little value because of the infrequent checks and interference with the recording thermograph by rodents.

Only a small amount of field time was spent tracking the birds released on Bear Spring Mountain because of the limited objectives of this phase of the study. A larger number of hens carrying radio-transmitters, easier access and earlier start of work at the Crumhorn Mountain study area were additional reasons for shifting emphasis to that area.

Periodic locations did not give detailed information on the movements of the three radio-equipped turkeys, but they did provide a summary of their wanderings. A considerable area, 1¼ miles east-west by 4½ miles north-south, surrounding the release site was known to have been covered by the birds during the 50-day tracking period (Figure 10). They did not move immediately and directly off the area as game farm-reared and locally trapped birds have been suspected of doing. If a movement into the major river valleys to the north or south of the mountain was to occur, it would probably have taken place shortly after the birds were released, but there was no evidence of this. All radio-locations showed the birds to be on the area, or in the immediate vicinity, for the entire tracking period.

None of the released birds was known to have been sighted during the tracking period; because of the nature of the Bear Spring Mountain area, this was not unexpected. Few people were afield on the area in spring and extensive hardwood cover hampered observation.

The last radio-location of transmitter #5 (Figure 10) appeared to represent a nest location as its signal remained stationary for a period of 1½ hours of continuous monitoring, but no further radio contact was made with this bird on successive visits to the area. It is possible that the bird lost its radio, or that some other circumstance

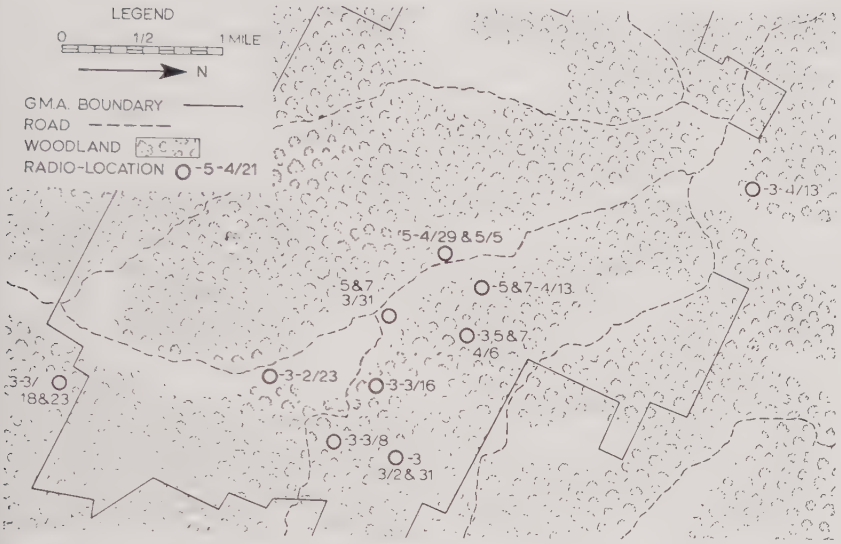


Figure 10. Spring movements of one male and two female transferred adult wild turkeys on the Bear Spring Mountain study area.

led to the stationary signal. However, at least one of the two hens equipped with radio-transmitters nested successfully since two broods accompanied by released hens were reported the following summer. Further credence is given to the theory that this location represented a nest site because one of the broods was seen nearby. The observation of a radio-equipped hen with a brood demonstrated that the transmitter and harness arrangement did not interfere with mating and nesting activities to the extent of precluding success.

Judging from the relative size of the poults at the times of observation, it is evident that the harsh spring weather of this section did not interfere with egg laying and incubation. Bear Spring Mountain is noted for its relatively severe climate and the storm of May 9-10, 1966, which covered the ground with 2 to 4 inches of wet snow, was not unusual. Mean temperatures of 40°-45° F. during April and under 55° F. for May prevail; mean precipitation is 3-4 inches and less than 3 inches for these two months, respectively; and annual snowfall averages 40-60 inches (Mordoff, 1925).

Ample information was collected during the 50-day tracking period to conclude that the released turkeys equipped with radio-transmitters did not leave the immediate area where they were released for any substantial length of time. Good evidence for a nesting attempt was collected solely by the use of telemetry and borne out by two brood observations during early summer.

Despite the similar sources of birds used in the Danby and Bear Spring Mountain studies, little direct comparison can be made between results. Differences in the sex of the released birds and characteristics of the area combined with unequal tracking periods, techniques and objectives to make the data not directly comparable. Nevertheless, the movements of the two groups of birds were characterized by much wandering about folowing release, and while this may not be the result in all similar introductions of birds from the southwestern region, it differed significantly from the suspected behavior of game-farm-reared stock and birds from the eastern region previously released on Bear Spring Mountain.

Crumhorn Mountain Study Area

Three to four days each week were spent locating the birds released on the Crumhorn Mountain area. For the three hens that were equipped with radios on March 2, locations were obtained on five days between March 2 and March 14. For these birds, and the two others that were equipped with radios on March 14, locations were obtained on 46 days between March 14 and June 1. Multiple locations were taken on several occasions. Although no location attempt was completely unsuccessful, it was common immediately preceding a transmitter failure to experience difficulty in maintaining contact long enough to take a precise bearing. Five attempts (9.8 per cent) were unsuccessful in locating all birds before their transmitters were considered off the air. A transmiter was considered dead on the day following final contact.

Two transmitters (#4 and #8) were not heard after April 26, another (#2) after June 1, while the last unit (#1) ran until July 18. Operation of transmitter #6 was terminated on June 9 after recovery from a dead hen. Expected lives were 188, 200, 158, 176 and 125 days, while actual field lives were 158, 111, 75, 119 (terminated) and 75 days, respectively. Again, no clear correlation with expected life was evident.

Premature radio failures combined with an unsuccessful nesting season to rule out observations on brood-rearing behavior. Considerable information on movement and activity was collected up to mid-incubation and the destruction of first nests. Five nests were located, four by radio-telemetry; none was successful.

Measurements of temperature and precipitation were taken at the two stations on Crumhorn Mountain from April 11 to May 31 in 1966. Unlike the Bear Spring Mountain area, no interference with the recording instruments was noted. During the late snowstorm (2 to 4 inches accumulation) and cold wave of May 9-10, one of the

hens (transmitter #1) thought to be incubating returned to the flock of toms; no other effect on nesting could be determined.

Percentage of activity, by week, in each of the four activity classes is presented in Figure 11, and percentage of "not active" measurements, by week, in Figure 12. Sample size fluctuated between 30 and 100 observations per week because of the relative mobility of the

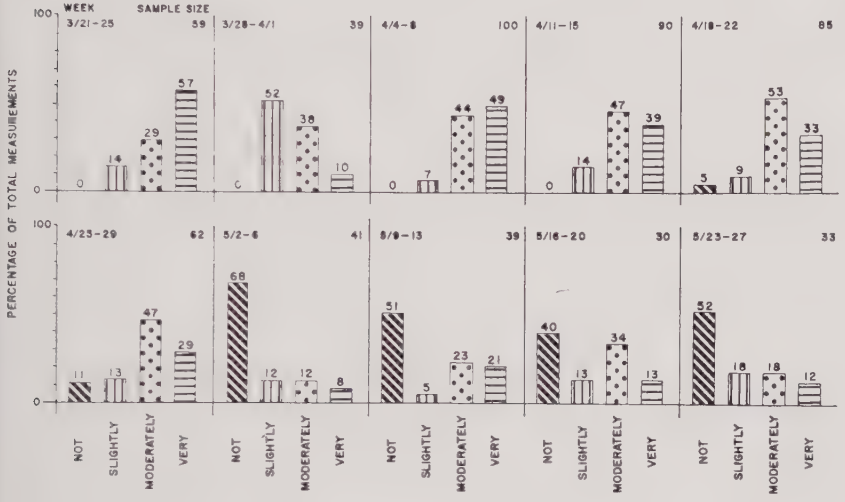


Figure 11. Percentage of activity measurements in four subclasses by week from March 21 to May 27 in 1966 on the Crumhorn Mountain study area.

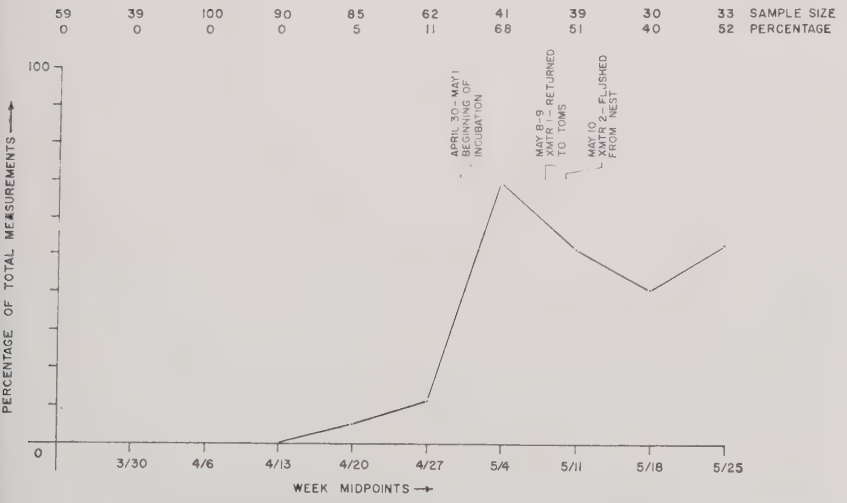


Figure 12. Percentage of "not active" measurements by week from March 21 to May 27 in 1966 on the Crumhorn Mountain study area.

birds and the number of operative transmitters. Since the hens were relatively sedentary until approximately April 1, few locations and, therefore, activity measurements were taken. From April 1 to 28, sample size was large because all transmitters were operating and the birds were quite mobile. After May 2, transmitter failures and immobility of the remaining hens greatly reduced sample size.

A pronounced increase in the "not active" category is apparent for the first week in May. Actually, the increase was apparent on May 2, when all three transmitters still operative were abruptly "not active". Since no activity was found in this category from mid-March to mid-April and only very slight incidence during the last two weeks of April, it was assumed that the sudden change in daytime activity indicated the start of incubation.

To verify this assumption, locations of the remaining three operative transmitters were made on the evening of May 5 from 7 to 11 p.m. Two hens (transmitters #1 and #6) remainded "not active" at their daytime locations; the third (transmitter #2) remained "not active" until just before dark (8:30 p.m.) when she became active and returned directly to the roost. The following day, extended monitoring of the first two hens revealed some very brief activity assumed to be comfort movements at the nest—proof that they were not dead. The third hen was later observed on a nest at the suspected nesting site.

Movement Until early April, the 11 birds traveled as a flock following a stereotyped movement and activity pattern. After leaving the roosting site (a farm woodlot comprising approximately 6 acres of mature and overmature white pine, white oak and red oak), they would consistently proceed to a nearby farm (Figure 13) to feed on waste grain in manure. The birds loafed in the vicinity and often visited the farmyard individually or in small groups throughout the day during early spring and inclement periods in late spring. As spring progressed, short early-morning and late-afternoon visits to the farmyard were still apparent, but there was less tendency to linger or return during mid-day. At roosting time, shortly before dusk, the birds characteristically fed through or around the farm enroute to the roosting area. This same roosting area had been in continuous use for at least 2 years, according to the woodlot owner. Since only a short time elapsed between leaving the roost and arriving in the farmyard, the farm appeared to be an established and preferred feeding area. Routine farm activities did not alter the flock's movements, and infrequent activities caused only brief changes in their normal pattern.

An area 1 mile east-west by 1¾ miles north-south contained all of the locations where the radio-equipped hens were recorded during the 158-day tracking period. Since the roosting site was certainly located, maximum movement in any direction was less than a mile; most movements radiated from the roosting-feeding complex toward the southeast. Length of movement was directly related to weather conditions, with longer and less predictable movements occurring as spring advanced. During the first two weeks of the study (March 2 to March 16), all locations were within ½ mile of the roosting area, but length of movement gradually increased to a maximum during the last week of April as weather conditions improved. In most instances, however, slight restriction of activity was noted in brief inclement periods during good weather.

Distances moved were short compared with those reported by other investigators (Dalke and Spencer, 1946; Glover, 1948; Latham, 1956; Mosby and Handley, 1943) using different field methods. Conversations with local residents verified that this was the typical late-winter and spring movement pattern of this flock. Even in other seasons, these birds did not venture much farther than a mile from the roosting site.

The occupancy of one small roosting area for such a length of time also does not appear typical of wild turkeys. Likewise, the repeated and persistent farmyard visits, when other food sources were available, is not typical.

Evidence of reproductive behavior (wing-drag marks in the snow) was noted on the first visit to the area (March 1). Gobbling and strutting were first observed on April 7. Intensive field observations were made from mid- until late April, and, while vigorous displaying was seen regularly, no copulations were observed.

Flock break-up occurred in early April when the hens began traveling in two or three small groups from midmorning through evening when they reunited with the other birds while returning to the roost site. The same hens did not invariably travel together each day, and by late April the five radio-equipped birds were often located individually. Movements before midmorning were similar to those earlier in the spring except that the flock spent less time in the farmyard, afterward traveling slowly, but directly, to a favorite displaying site ¼ mile from the roost area (Figure 13). While gobbling and strutting were not confined to this area, they were more intensified and prolonged there, definitely appearing to be the major activities taking place.

It was at this time that the observed behavior of the toms was most atypical of wild turkeys. The three adults and one juvenile remained

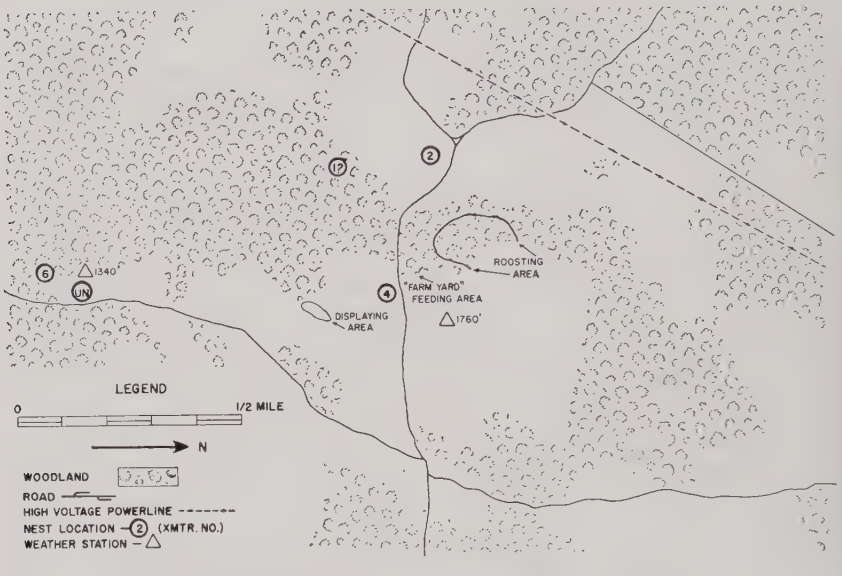


Figure 13. Map of the Crumhorn Mountain study area.

together throughout late winter and spring, traveling with the hens when they were available.

From daybreak, when the birds left the roost, until 7:30 to 8:00 a.m. gobbling was frequently heard. However, when the flock was followed and observed, the gobblers were seen to be a more or less distinct subgroup, reacting more among themselves than with the hens. Little opportunity for mating existed before observations were possible in the morning since very little time elapsed between flying down from the roost and arrival in the farm area, sometimes as little as 10 minutes.

Basically, whenever one tom began strutting, it triggered the same behavior in the other three with the result that they displayed to each other while the hens often fed for a considerable distance before the toms ceased displaying to catch up with them. Only one instance of agonistic behavior was seen, and local residents reported little during the spring. On March 29, two adult toms were observed in a spirited dispute lasting approximately 3 minutes before one bird fled from view with the other in pursuit. Observations on succeeding days did not reveal any apparent change in their behavior pattern.

The spring feeding behavior of the four toms was also quite atypical. Breast sponges were evident on all four birds throughout the study, yet they demonstrated as much interest in feeding as did the hens. During intervals when they were not actively displaying, the toms usually fed vigorously. Some appeared to be displacement

feeding occurring after strutting, especially when the hens fed away from them. This was especially noticeable when the birds were moving from the farmyard to the displaying site. However, at other times of day when the toms were observed, their feeding behavior appeared to be true foraging.

The juvenile tom behaved almost identically with the three adults. Two differences were noted: (1) his displaying (gobbling and strutting) was less intense than that of the adults; and (2) when not displaying, he often mingled and fed with the hens more than the adult toms did.

NESTING Five wild turkey nests were located during the study, four of transmitter-equipped birds (#1, #2, #4 and #6) and one of an unbanded bird assumed to be the one uncaptured hen in the flock. Nest locations corresponded well with the general area each radio-carrying hen frequented during the two weeks (April 18 to

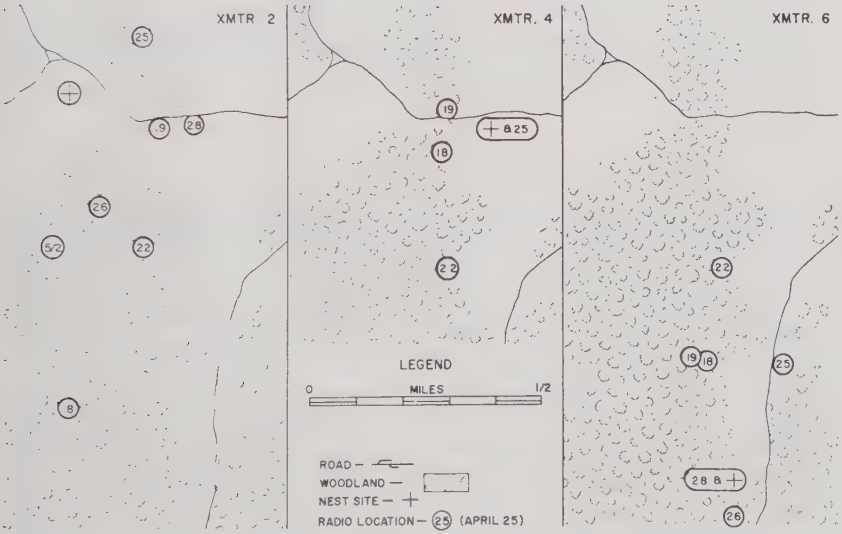


Figure 14. Locations of hens equipped with transmitters #2, #4 and #6 during the two weeks preceding incubation (April 18 to May 2 in 1966) on the Crumhorn Mountain study area.

April 31) preceding the start of incubation (Figure 14). Although there is no definite proof, it seems more than coincidence that the first "not active" measurements (on April 19) were recorded 2 weeks prior to the start of incubation (April 30 to May 1) since this would correspond closely with the calculated start of egg laying based on the observations of Mosby and Handley (1943).

The hen carrying transmitter #1 selected a nest site in the woods approximately ¼ mile southwest of the roosting area (Figure 13). The actual nest site was not located. She deserted the nest on May 8 or 9 shortly before, or during, a late snowstorm. It is strongly suspected that she deserted because of this storm, but the evidence is circumstantial. In addition to the coincidence of the storm and the hen's return to the toms, there was no evidence of feather loss, physical injury or "nervousness" to indicate disturbance by a predator.

A mound of earth adjacent to a small stream served as a nest site for the hen marked with transmitted #2 (Figures 13 and 15). Repeated locations of this hen were made by radio while she was on the nest, but she could not be observed despite much scanning of the immediate area with binoculars and a spotting telescope. In order to locate the nest site exactly, the hen was flushed at very close range. Eleven eggs were found, and subsequent visits revealed no evidence of the hen's return. Radio locations after the day of desertion placed her near or with the four gobblers.

Cause of desertion for the hen equipped with transmitter #4 is unknown. On May 2, she was inadvertently flushed from a nest of 13 eggs. The nest location coincided with the last radio location of the hen (April 26, Figures 13 and 16). She was observed on the nest again on May 3, but she was not seen at the nest during or after the May 9 snowstorm. When the snow had melted, another check was made and, while the eggs were not found, the nest cavity was located and a few tail feathers were found nearby. The farmer who owned the roosting and feeding areas had noticed this hen in company with the toms the day preceding the storm. From her "nervous" behavior and the evidence at the nest site (missing eggs and scattered tail feathers), it seems probable that some predator attacked the hen and disrupted her nesting attempt.

The hen carrying transmitter #6 was located at her nest site more often than the other three radio-marked nesting birds (Figure 13). On May 13, she was observed feeding along a field edge adjacent to the nest site. This was the last date on which an "active" signal was received from this transmitter. On June 9, approximately 10 days after the caluculated hatching date, the area was searched and the transmitter and remains of the hen were found. A search was not made earlier for fear of disturbing the bird. The hen had been killed about 2 weeks earlier, most probably by a fox or dog. Despite a wide search, neither the nest cavity nor egg-shell remains could be located.

The nest of the unbanded hen was located after several egg shells were found around weather station #1 (Figure 13). Crow and raccoon were the nest prediators identified from marks on the shell

Figure 15. Nest site (above) and nest cavity (below) of hen equipped with transmitter #2.

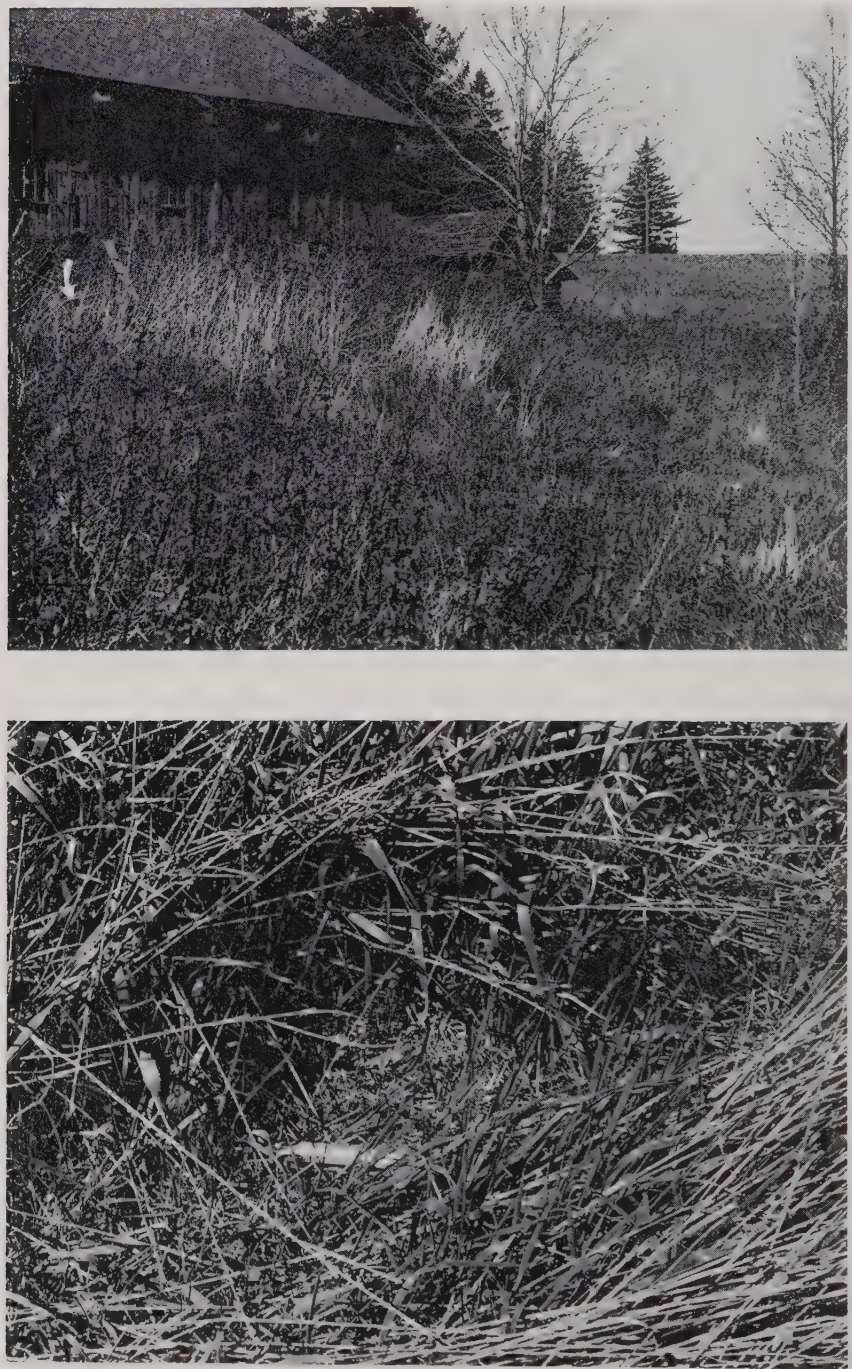


Figure 16. Nest site (above) and nest cavity (below) of hen equipped with transmitter #4.

fragments. On May 24, a search of the immediate area flushed the hen from a nest of seven eggs within 200 feet of the weather station (Figure 17). Although obviously disturbed, she moved off slowly. On May 26, she was observed incubating. Subsequent checks of the nest when the hen was not incubating showed a gradual decline from seven to four eggs in one week. The hen deserted and returned to the roosting area over the Memorial Day weekend when picnickers used the nest site area. Although this hen tolerated a great deal of disturbance, desertion can probably be attributed to combined predation and human disturbance.

During the period after the first nesting failures, when the radios were functioning properly, the hens returned to, and remained with, the toms. Renesting attemps could not be identified because of subsequent transmitter failures. However, a brood of three poults accompanied by a banded hen was reported on June 22; their size at that time indicated a second nesting attempt.

The three nests found were located in situations typical of wild turkey nesting sites as described by Latham (1956) and Mosby and Handley (1943). From what is known of the locations of the other two nests, it is probable that they were also located typically. However, the type of situation in which nests were found on this area in 1966 differed from that of previous years. The previous nests were found only along field edges, or within fields, and were not found until mid-June and July. It is suspected that these were second-nesting attempts detected during haying operations. In these same years, first attempts may have been located in situations similar to those of 1966, and the reason for the change in sites between first and second nestings is believed to have been a change in available nesting cover. At this latitude and elevation, grass/legume vegetation has not developed sufficiently by mid- to late April to provide adequate cover for a nesting wild turkey, whereas by late May it has. Haying operations commencing in mid-June disrupt many of these renesting attempts. Combined with the availability of nesting cover may be a tendency for these birds to nest in, or near, field situations.

The low nesting success in 1966 appeared to be characteristic of this flock. In five breeding seasons after the original liberation of 10 birds, there was an increase to 12. Coupled with low nesting success, was a high mortality among the poults until they were approximately 12 to 16 weeks old. This may have been caused by little ability of the hens to raise a brood, as observed in Virginia by Mosby (1940). The adult birds were relatively long-lived; of the nine birds captured in 1966: two had been banded 1 year; one, 3 years; and one, 4 years previously. One bird of nine captured was a juvenile.

Figure 17. Nest site (left) and nest cavity (right) of unbanded hen.

Activity Measurements The application of telemetered activity measurements to defining the onset of incubation clearly demonstrated the usefulness and versatility of radio-telemetry technique. The start of incubation was determined, for this particular study area and year, within a 2-day period (April 30 to May 1). Extended monitoring of activity indicated that some hens may remain at the nest for long diurnal periods and return to the roost at night. The extent and significance of this behavior is not known.

DISCUSSION

Implications of the results of this study relate primarily to the telemetry system and its use and to turkey management.

Telemetry System

The system constructed and used for this study was adequate for tracking wild turkeys on three study areas. The Bear Spring Mountain study was the most severe as a test of the equipment's capabilities. Most radio-telemetry work with wild turkeys in New York will undoubtedly be done on similar areas.

The poor road network on and off the game management area necessitated extra time to get to a position to take a bearing, and quite often an advantageous position could not be used because the range was excessive. At other times, due to long range and/or rough topography, a signal was either too week, or required additional time, to provide an accurate bearing.

More frequent trips to the area might have relieved some of the problem by allowing less time for the birds to move between attempts to locate them. The range problem might be resolved in a number of ways: (1) acquire a hand-portable receiver, (2) increase the output power of the transmitter, or (3) increase the sensitivity of the receiver-antenna system. Because of the desirability of maximum transmitter life and minimum weight, alternatives 1 and 3, or a combination of them, are considered most suitable.

The transmitter has two main drawbacks, i.e., a somewhat cumbersome loop antenna and heavy weight. Incorporating the fixed-size loop as a part of the harness arrangement does not allow for growth; use on juvenile birds is, therefore, restricted. Pulsed-signal transmitters may be a means of reducing transmitter weight while maintaining long life. However, it is not known how much power (weight) could be saved or what new problems might attend such a unit.

Turkey Management

This project did not provide for a detailed appraisal of suspected differences between wild turkeys from southwestern (Region

2) and eastern (Region 7) New York. Because of circumstances described, e.g., differences in sex, age and source of the turkeys studied, plus unequal tracking periods, variations in technique, and the objectives of the project, direct comparisons cannot be made between results from the different study areas. Nevertheless, the author is convinced that real differences exist in the two types of stock. This opinion is based on conversations with regional personnel of the State Conservation Department, personal observation and comparison of the movements and behavior of the telemetered birds.

Basically, eastern birds appear to be less mobile, less productive and less wary of man than birds from the southwestern region. Although wariness of the eastern birds increased after the first hunting season in 1963, a marked difference between the two strains was still noticeable. Significant management implications of the first two points are quite obvious since both have an important effect on the rate of dispersal and establishment in new range.

Past experience has shown the majority of introductions of game farm turkeys, to establish or re-establish a population, to have been unsuccessful and expensive. Introductions in New York have been no exception. Although wild turkey populations may result from plantings of game farm stock, the resultant population may not be characteristic of the native eastern wild turkey and may be unsuited for its intended purpose. In the past two decades, wild-trapped birds have proven superior to game farm stock in the introductions made. Trapping wild turkeys is often slow, difficult and costly (per bird), but a high quality bird, unattainable by other means, is made available for stocking by this method.

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AGE AND GROWTH OF SCUP IN THE WATERS OF EASTERN LONG ISLAND[1]

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ABSTRACT

From May 1964 through September 1966, age and growth data were obtained for more than 3,000 scup collected with different types of gear at several locations in the waters of eastern Long Island. Scale annuli were identified and, based on the time of formation and their location on the scale, were considered to be valid indicators of age. Fish lengths were back-calculated, and the average growth rates for males and females were determined. The size and age composition of the fish collected are presented and discussed. While additional biological information would be required for full evaluation, it appears that the present minimum size (7 inches) for scup that may be legally bought and sold is of doubtful value.

The scup (*Stenotomus chrysops*) is a migratory species which enters inshore New York waters in late April and usually departs by October or early November. While in these waters, it is taken by both commercial and sport fisheries.

Scup ranked first both in monetary value and in total poundage among the edible, commercial fin fish landed in New York State each year from 1956 to 1966. Over 10 million pounds valued at between $700,000 and $900,000 were landed each year during the period 1956 through 1962. However, it appears that, in more recent years, the fishery has entered a period of decline, as evidenced by the decrease in catch from more than 14 million pounds in 1958 to slightly over 4 million pounds in 1966 (Table 1).

The commercial fishery for scup, which began in colonial times, is quite extensive both in the geographical area involved and in the types of equipment employed. Descriptions of the gear used and the locations fished may be found in the works of Goode (1884), Bean (1903), Pearson (1932), Dickerson (1939), Bigelow and Schroeder (1953) and Neville and Talbot (1964).

The exploitation of this fish by the sport fishery also extends into historical times. DeKay (1842), for example, stated that "It affords much sport to fishing parties, who go outside of the harbor in steam vessels and take them in great numbers." While not well documented, it would appear that at present, the harvest of scup in New York may be nearly as great for the sport fishery as for the commercial fishery. In the Peconic Bay area alone, Briggs (1968) found that in the 3-year period from 1964 through 1966, during the months of May to November, 167,000 anglers specifically seeking scup caught 2.2

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R.

TABLE 1. COMMERCIAL CATCH OF SCUP IN NEW YORK, 1956–1966*

Year	Value (dollars)	Weight (pounds)
1956	721,659	10,851,171
1957	807,680	11,761,265
1958	907,897	14,319,291
1959	834,712	13,489,826
1960	767,015	12,969,235
1961	873,701	12,054,960
1962	743,548	10,694,815
1963	783,613	9,307,715
1964	783,648	8,343,820
1965	746,701	7,536,888
1966	637,078	4,077,028

* Source: New York Landings, annual summaries 1956–1966. U.S. Bur. Comm. Fish. and N.Y.S. Bur. Marine Fish. (published by U.S. Dept. Int.)

million of this species. Scup are also caught in great numbers in other New York waters such as the "Tin Can Grounds" located in the Atlantic Ocean off Rockaway (western Long Island) and in scattered sections of Long Island Sound. However, catch data for the sport fishery for scup in these areas are unavailable.

Moreover, the great importance that scup play in the sport fishery is not limited to New York. In a survey conducted by the New Jersey Division of Fish and Game, Younger and Zamos (1955) reported that almost 2 million pounds of scup were caught in 1954 in New Jersey waters, ranking it in third place among species caught by sport fishermen. Over 7 million pounds of scup were taken by commercial fishermen in New Jersey during that same year.

In the future, scup should be of even greater importance to the sport fishery because of the rapid rate of increase among hook-and-line anglers. In 1955, there were 608,000 marine anglers in New York State (Crossley, S-D Surveys Inc., 1956). According to Stroud (1963) this figure has increased by about 6.7 per cent per year. Thus, by extrapolation it is estimated there will be approximately 1,618,000 marine anglers in New York by the end of 1970. It seems obvious that many of these fishermen will devote a good portion of their effort to fishing for scup.

Because of the value of the scup to these fisheries, certain aspects of its life history need to be understood in order to implement sound management. Moderate amounts of information about spawning and early development are recorded in the works of Goode (1884), Bean (1903), Kuntz and Radcliff (1917), Nichols and Breder (1926), Perlmutter (1939), Merriman and Sclar (1952), Bigelow and Schroeder (1953), Wheatland (1956), Marak and Colton (1961), Marak

et al. (1962), Anonymous (1962) and Herman (1963). Data dealing with the growth of this fish are limited to the literature of Bean (1901, 1903), Nichols and Breder (1926), Neville *et al.* (1939), Perlmutter (1939), Breder (1948), Bieglow and Schroder (1953), Anonymous (1962) and Smith (1965). The present study was undertaken in an attempt to add to the knowledge of the age and growth of this extremely valuable marine resource.

METHODS AND MATERIALS

Otter trawls, haul seines and angling gear were used to sample the scup population in the Peconic Bays, located at the eastern end of Long Island (Figure 1), during the periods of May 20 to October 23 in 1964, May 5 to October 8 in 1965 and May 11 to September 29 in 1966.

Adult, sub-adult and juvenile scup were captured with an otter trawl fished from a 40-foot research vessel. The net employed was a "balloon type" otter trawl of 3-inch stretch mesh with a 36-foot head rope and a 3-inch stretch mesh cod end. In mid-July, a 3/8-inch stretch mesh liner was inserted in the cod end to permit collections of juveniles in deep water. From July to the end of the sampling period, trawling was carried out on a daily (weekday) basis for 2-week periods followed by a week of daily haul seining.

Seining was conducted to collect juveniles from mid-July through early October with a small-mesh nylon haul seine. This seine was 300 feet long by 6 feet deep and was comprised of 1 1/8-inch stretch

Figure 1. Map of Long Island showing location of Peconic Bays.

mesh in the outer sections of the wings, ¼-inch knotless mesh in the inner sections of the wings and ⅛-inch knotless mesh in the pocket.

During June of 1965 and 1966, the research vessel was unavailable because of other commitments. Consequently, during these periods, adult and sub-adult scup were sampled by hook-and-line angling from an outboard-powered rowboat. Scup were captured on sport fishing gear consisting of No. 6 long-shanged hooks, 2- to 4-ounce sinkers and such natural marine baits as bloodworms (*Glycera* sp.), hard clams (*Mercenaria mercenaria*), skimmer or surf clams (*Spisula solidissima*) and squid (*Loligo pealii*).

The fish were dissected in the field, and sex was determined by gross examination of the gonads. All specimens were measured to the nearest 5 millimeters in fork length. A scale sample was taken from the left side of each fish in the area of the distal portion of the pectoral fin and was placed in a labeled scale envelope for later examination.

In the laboratory, visual examination of the scales resulted in the discarding of obviously regenerated scales. Then, 8 to 12 scales from each sample were selected. These were placed on a 1-inch by 3-inch by 0.05-inch-thick strip of transparent cellulose acetate. Impressions of the scales were made by using a Carver Model B hydraulic press set at 175° F. and 6,000 pounds-per-square-inch pressure for 3 minutes. The scale impressions were examined in an Eberbach reflex microprojector at 40-power magnification. From each sample, a single scale was chosen at random for measurement. Measurements of the distance from the facus to each annulus and to the anterior scale edge (measured along the first primary radius in the left lateral field) were made directly on the viewing screen with a standard millimeter rule. Doubtful scale readings and measurements were repeated for verification when necessary.

The fish length-scale length relationship was determined by means of regression analysis. The data were separated by sex, lengths at previous ages were back-calculated and these data were subjected to analysis of variance. Growth rates for male and female scup were determined by fitting a von Bertalannfy growth function to the age-length data. Length- and age-frequency distributions of the scup were calculated and are presented graphically.

SCALE GROWTH AND ANNULUS FORMATION

The criteria established by Edwards *et al.* (1960) for identifying annuli on scup scales were used. Fish were assigned an age group based on the number of annuli present on the scale, and also according to the time of year the specimen was collected. One year of age

was allotted for each annulus. However, if there was no indication of the formation of a new marginal annulus on scales collected in the spring or early summer, then these scales were arbitrarily assigned to the next higher age group. The width of the growth increment between the last annulus and the scale edge was the factor which was used to determine whether or not the marginal annulus was formed during the current year or in the preceding year. The assumption was made that, if the growth increment was small (25 millimeters or less at 40-power magnification), the annulus in question was formed in the current year; if the growth increment was large (more than 25 millimeters at 40-power magnification), the last annulus on the scale had been produced in the previous year. Using this technique, it is believed that the fish collected during the spring and early summer were correctly placed in their respective age groups.

Frequency distributions of the distances from the focus to each annulus and from the focus to the anterior margin of the scale for various age groups are presented in Figures 2 through 5. The data in Figure 2 suggest that annulus formation in yearlings occurs primarily before June (most probably during May). Of 84 one-year-old scup taken in June, 82 had already formed an annulus. By July, scales from all 224 yearling scup examined showed evidence that the annulus was formed. The annular distances for scales of yearlings from June through October closely overlapped the marginal distances for scales of young-of-the-year fish collected during September (Figure 3). It would appear that, following rapid early development, scale growth was considerably reduced during the winter and the first annulus was formed on the margin of the accrued growth of young-of-the-year fish. Following the time of annulus formation, rapid growth ensued, as indicated by the increase in marginal distances from June through October. Observations similar to these have been reported by Pacheco (1962) for the spot (*Leiostomus xanthurus*), Massmann (1963) for the weakfish (*Cynoscion regalis*) and Schaefer (1965) for the northern kingfish (*Menticirrhus saxatilis*).

Annulus formation in 2-year-old scup appears to have occurred slightly later than in yearling fish (Figures 4 and 5). Of 226 specimens examined during June of 1964, only five had formed a second annulus, but, by July of 1964, 71 of 78 fish sampled had a well defined second annulus. Although only five 2-year-old scup were collected during August of 1964, all exhibited the second annulus. Similar observations were made for specimens collected during 1965. In June, five of 13 scup had formed the second annulus and, by July, 59 of the 62 fish examined showed evidence of the second year mark. All 2-year-old scup (176) collected in August had formed the second annulus.

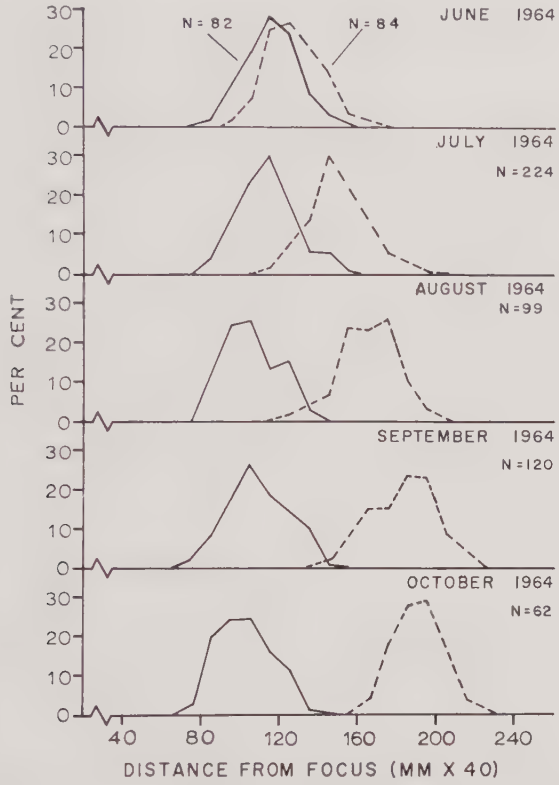

Figure 2. Monthly frequency distributions of distances from focus to annulus (solid lines) and to anterior margin (dotted lines) of scales from yearling scup collected during 1964.

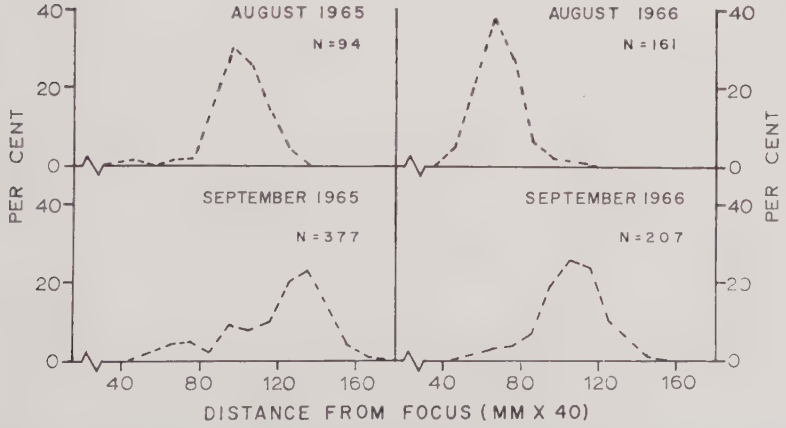

Figure 3. Frequency distributions of distances from focus to anterior margin of scales from young-of-the-year scup collected by various types of gear during 1965 and 1966.

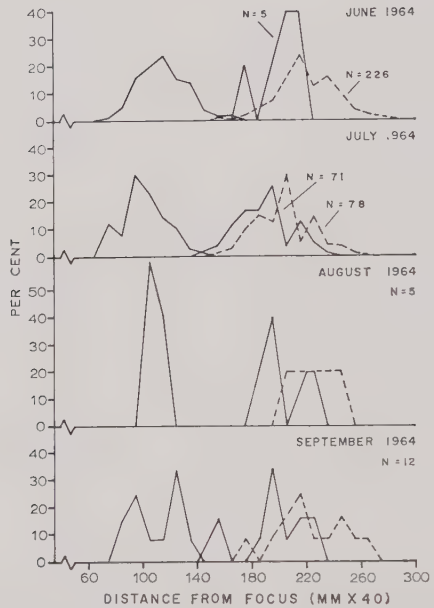

Figure 4. Monthly frequency distributions of distances from focus to annuli (solid lines) and to anterior margin (broken lines) of scales from 2-year-old scup collected during 1964.

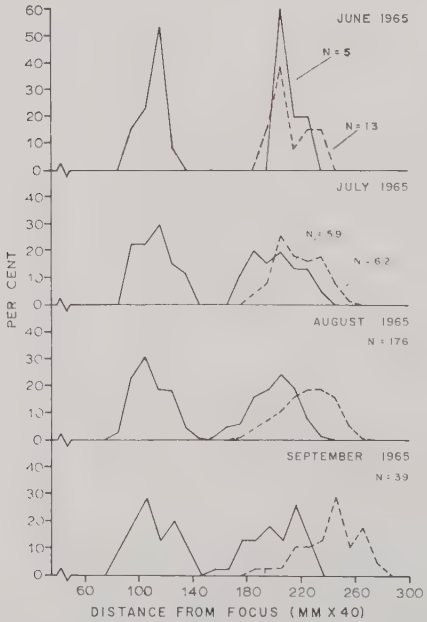

Figure 5. Monthly frequency distributions of distances from focus to annuli (solid lines) and to anterior margin (broken lines) of scales from 2-year-old scup collected during 1965.

Distance from the focus to the second annulus for scales sampled from June through September corresponded well with the marginal distance for yearlings sampled in October (Figure 2). These data suggest that scale growth was again curtailed during the winter and that the annulus was formed on the margin of the growth increment which had been laid down during the previous year. It appears, however, that scale growth following formation of the second annulus is slower than the scale growth that followed the formation of the first annulus.

Similar observations for scales from scup older than 2 years were too few to warrant further analysis. Nevertheless, from the foregoing data, it seems reasonable to conclude that, since annuli were formed at approximately the same time of year in each of two different age groups and were located on the margin of each preceding year's scale growth, scale annuli are true year marks and, as such, can be used as valid indicators of age.

FISH LENGTH-SCALE LENGTH RELATIONSHIP

Calculation of the fish length-scale length relationship is requisite to determining the lengths of fish at the time of annulus formation. By using the method of least squares, the general linear function, where

$$X_1 = a + b_{12}X_2$$

was fitted to 3,023 paired observations. The resulting equation

$$X_1 = 0.55 + 1.110X_2$$

is presented in Figure 6. A correlation coefficient (r_{12}) of 0.960 was obtained, indicating a high degree of relationship between the two variables. An analysis of variance (Table 2) indicated that the relationship did not differ significantly from linearity and was best described by the straight line function.

TABLE 2. ANALYSIS OF VARIANCE OF FISH LENGTH-SCALE LENGTH LINEAR REGRESSION FOR 3,023 SCUP

Source of variation	Degrees of freedom	Sum of squares	Mean square	*F*	
				Value	Reference value*
Total	3,022	15,150,004.59			
Regression	1	13,951,888.35	13,951,888.35	35,179.10**	6.64
Deviations from regression	3,021	1,198,116.24	396.60		

* At 1 per cent level of probability.
** Highly significant.

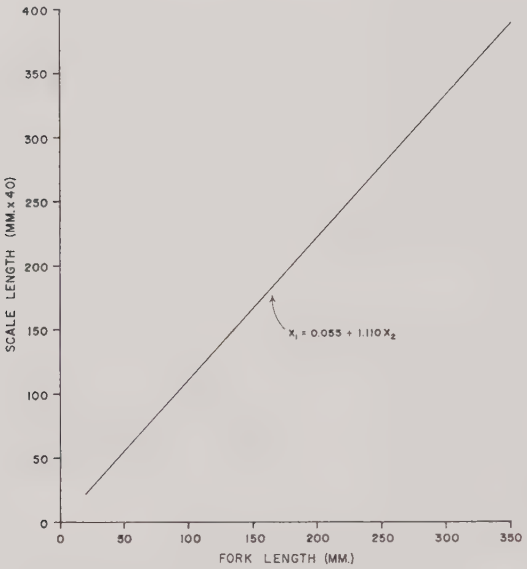

Figure 6. Relationship of fish length to scale length for 3,023 scup.

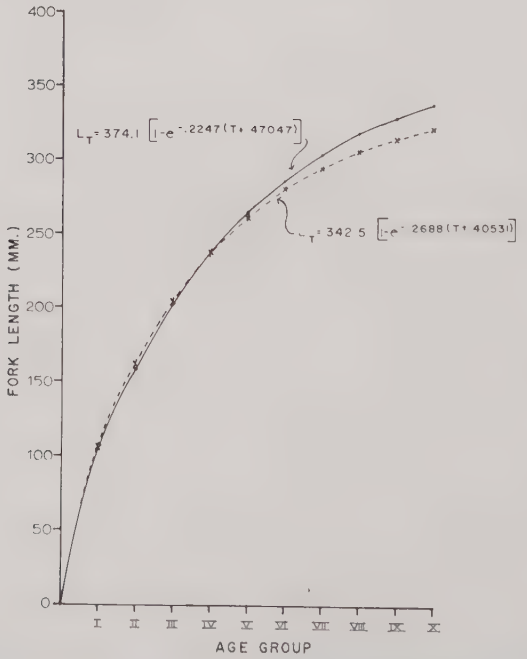

Figure 7. Growth rates of male scup (broken line) and female scup (solid line) computed from back-calculated lengths at previous ages in Table 3.

AGE-LENGTH RELATIONSHIP

Employing the formula

$$L_n = C + \frac{S_n (L_t - C)}{S_t}$$

where,

L_n = length of fish at time of formation of nth annulus
L_t = length of fish at time of capture
S_n = distance from focus of scale to nth annulus
S_t = distance from focus of scale to anterior margin
C = the X-axis intercept of the function which describes the fish length-scale length relationship ($C = -0.05$)

back-calculations of fish lengths at previous ages were obtained for 100 male and 100 female scup. These fish were randomly selected from over 2,000 samples which had been stratified by age group. The data are presented in Table 3.

An analysis of variance was performed on the apparent differences between the sexes, and the differences were found to be significant (Table 4).

Following the procedure outlined by Tomlinson and Abramson (1961), the von Bertalannfy growth-in-length function

$$L_t = L\infty \left[1 - e^{-k\ (t_n - t_o)} \right]$$

where,

L_t = length at age t
$L\infty$ = maximum expected length (asymptote)
k = constant which is proportional to the rate of destruction of body materials
t_o = hypothetical age at 0 length
t_n = age of fish in nth age group, where $t_1 = 0$

was fitted separately to the data for each sex by the method of least squares. The resulting functions

$$\text{males: } L_t = 342.5 \left[1 - e^{-0.2688\ (t_n + 0.40531)} \right]$$

$$\text{females: } L_t = 374.1 \left[1 - e^{-0.2247\ (t_n + 0.47047)} \right]$$

are presented graphically in Figure 7 and indicate that male and female scup attained respective average sizes of 107.7 and 105.3 millimeters at age I, 163.1 and 159.3 millimeters at age II, 205.4 and 202.6 millimeters at age III, 237.7 and 236.9 millimeters at age IV, 262.4

Table 3. Frequency Distributions of Back-calculated Lengths at Previous Ages for 200 Scup Sampled Between May 1964 and September 1966*

Fork length (millimeters)	Age group and sex																			
	I		II		III		IV		V		VI		VII		VIII		IX		X	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
60– 69	1	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
70– 79	8	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
80– 89	16	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
90– 99	19	22	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
100–109	25	20	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
110–119	13	19	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
120–129	12	7	3	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
130–139	5	2	10	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
140–149	1	2	6	6	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
150–159	..	..	7	14	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
160–169	..	1	11	8	2	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..
170–179	..	..	22	14	6	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..
180–189	..	..	15	14	12	15	2	2	..	..	..	..	..	..	..	..	..	..	..	..
190–199	..	..	12	7	8	7	2	3	..	..	..	..	..	..	..	..	..	..	..	..
200–209	..	..	2	6	14	14	7	3	1	1	..	..	..	..	..	..	..	..	..	..
210–219	..	..	..	2	16	6	8	7	1	2	1	..	..	..	..	..	..	..	..	..
220–229	..	..	..	..	7	15	9	14	4	2	..	1	..	..	..	..	..	..	..	..
230 239	..	..	..	1	8	8	17	8	6	3	1	2	1	1	..	..	..	..	..	..
240–249	..	..	..	..	6	4	12	14	10	14	4	..	..	..	..	..	..	..	..	..
250–259	..	..	..	..	..	1	6	11	15	6	4	7	3	1	..	..	..	..	..	..
260–269	..	..	..	..	..	..	4	5	10	13	9	6	1	3	..	..	..	..	..	..
270–279	..	..	..	..	..	..	2	3	6	9	13	7	4	3	1	2	..	..	..	..
280–289	..	..	..	..	..	..	1	..	4	8	8	8	11	5	2	2	..	..	..	..
290–299	..	..	..	..	..	..	..	..	..	1	3	15	8	7	7	2	1	1	..	..
300–309	..	..	..	..	..	..	..	..	2	1	4	2	6	10	6	5	6	2	1	..
310–319	..	..	..	..	..	..	..	..	1	..	1	1	3	7	7	9	4	5	3	2
320–329	..	..	..	..	..	..	..	..	..	..	2	1	..	2	3	6	3	5	4	3
330–339	..	..	..	..	..	..	..	..	..	..	..	..	3	..	2	3	5	3	1	1
340–349	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	..	..	3	1	..
350–359	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	3
360–369	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1
Total	100	100	90	90	80	80	70	70	60	60	50	50	40	40	30	30	20	20	10	10
Mean length	102.5	101.8	167.8	165.2	207.0	206.0	233.5	235.8	256.5	259.3	275.0	278.9	291.1	296.5	308.9	312.5	318.5	325.7	323.3	337.0

* Ten males and 10 females were selected at random from each age group, and the back-calculations were cumulative.

TABLE 4. ANALYSIS OF VARIANCE OF AGE-LENGTH DATA FOR SCUP

Source of variation	Degrees of freedom	Sum of squares	Mean square	*F*	
				Value	Reference value*
Total	1,099	6,485,641.67			
Age	9	4,653,147.74	517,016.42	521.35**	2.41
Sex	1	511.27	511.27	0.52	6.64
Age vs. sex interaction	9	760,967.09	84,551.90	85.26**	2.41
Within subclasses	1,080	1,071,015.57	991.68		

* At 1 per cent level of probability.
** Highly significant.

and 264.6 millimeters at age V, 281.3 and 286.7 milimeters at age VI, 295.7 and 304.2 millimeters at age VII, 306.7 and 318.3 millimeters at age VIII, 315.4 and 329.5 millimeters at age IX, and 322.9 and 338.5 millimeters at age X. Although scup as much as 15 years old were collected during this study, the percentage of fish above age X was quite small. Therefore, for ease in calculating the von Bertalannfy growth-in-length function, age X was set as the maximum age for which there was an adequate sample of data. Lengths of fish beyond age X may be extrapolated from Figure 7.

From the growth curves depicted, it was observed that the maximum average expected lengths were 342.5 millimeters for male scup and 374.1 milimeters for female scup. It was determined mathematically from these observations that males and females, respectively, attained 31.4 and 28.1 per cent of their maximum expected length by age I, 47.6 and 42.5 per cent by age II, 60.0 and 54.2 per cent by age III, 69.4 and 63.3 per cent by age IV, 76.6 and 70.7 per cent by age V, 82.1 and 76.6 per cent by age VI, 86.3 and 81.3 per cent by age VII, 89.5 and 85.1 per cent by age VIII, 92.1 and 88.1 per cent by age IX and 94.3 and 90.5 per cent by age X.

Length-Weight Relationship

Data pertaining to the length-weight relationship of scup may be found in Briggs (1968) for eastern Long Island and in Smith (1965) for marketable scup landed in Hampton Roads, Virginia.

LENGTH AND AGE COMPOSITION OF THE CATCH

The different sampling gears tended to select fish of different sizes. Thus, the length and age data were separated by type of gear.

Catch by Hook and Line

Frequency distributions according to length and age for the scup collected by hook and line during June of 1965 and 1966 are presented in Figure 8. In June of 1965, 71 specimens ranging from 160 to 350 millimeters in length were collected. Nine age groups were represented by these fish. Age groups II through VI accounted for 94.4 per cent of the catch, while the remaining 5.6 per cent included fish from age groups VII, X, XI and XII. Two- and 3-year-old fish alone

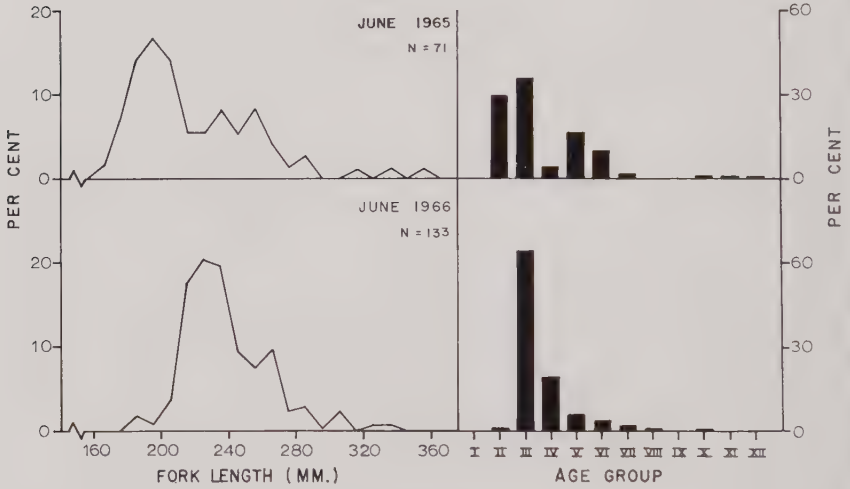

Figure 8. Length- and age-frequency distributions of scup taken by hook and line during June of 1965 and June of 1966.

comprised 64.8 per cent of the catch, and age groups V and VI accounted for an additional 25.4 per cent.

During June of 1966, 133 scup ranging from 180 to 330 millimeters in length were sampled. Eight age groups were represented, viz., ages II through VIII, and X. Three- and 4-year-old fish together accounted for 84.2 per cent of the catch, while ages II, and V through X ranged from 6 per cent to less than 1 per cent of the total. The dominant group was age III, constituting more than 64 per cent of all specimens. This was the same group that accounted for almost 30 per cent of the catch in 1965.

Briggs (1968) graphed the catches of scup made by anglers who fished from rowboats in the Peconic Bays for June of 1965 and 1966. The size ranges he observed were very similar to those observed for hook-and-line catches during the present study.

CATCH BY HAUL SEINE

Haul seining at various shore locations in Great Peconic Bay and Little Peconic Bay (Figure 9) yielded primarily young-of-the-year scup. During 1964, no scup was caught by this method. Although haul seining commenced each year in mid-July, the first scup collected by this gear was taken on August 16 in 1965. A total of 34 young of the year, ranging in length from 50 to 105 millimeters with an average of 91 millimeters were secured in August. In September of 1965, 194 specimens were collected; only one (120 millimeters long) was 1 year

Figure 9. Map of Peconic Bay area with seining sites marked by X.

old while the remainder, which ranged in length from 95 to 140 millimeters with an average of 118 millimeters, were young of the year. In 1966, 78 young of the year, ranging from 50 to 95 millimeters in length with an average of 66 millimeters, were collected in August, while 102 young of the year, ranging in length from 75 to 125 millimeters with an average of 97 millimeters, were collected in September. The length-frequency distributions of these fish are illustrated in Figure 10.

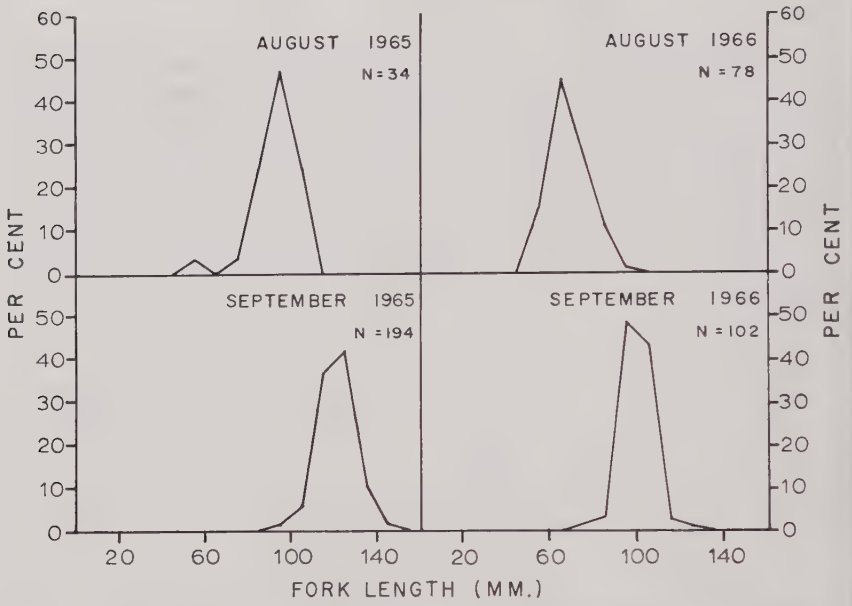

Figure 10. Length-frequency distribution of scup caught by haul seine during August and September of 1965 and 1966.

Catch by Otter Trawl

The otter trawl proved to be the most efficient type of gear used in this study to collect wide size and age ranges of scup. The specimens ranged in length from 105 to nearly 400 millimeters and represented ages from 1 to 15 years. While many age groups were represented, the majority of the fish were from 1 to 6 years old.

In June and July of 1964, the catches were dominated by fish of age group II. The size and age composition changed as the season progressed and, by August and September, 1-year-old fish constituted the majority of the catch (Figure 11).

Collections made in 1965 indicated extensive size and age distributions during May and June. At that time fish as old as age XII were present. By July, however, the age composition had changed radically, and only 2- and 3-year-old fish were represented (Figure 12). The 1963 year class, which dominated the catches in August and September of 1964, also dominated the catches in July and September of 1965.

Age and length data for otter trawl catches in 1966 were available only for May (Figure 13). However, the age and size composition of these catches were similar to those for the same month in 1964 and 1965.

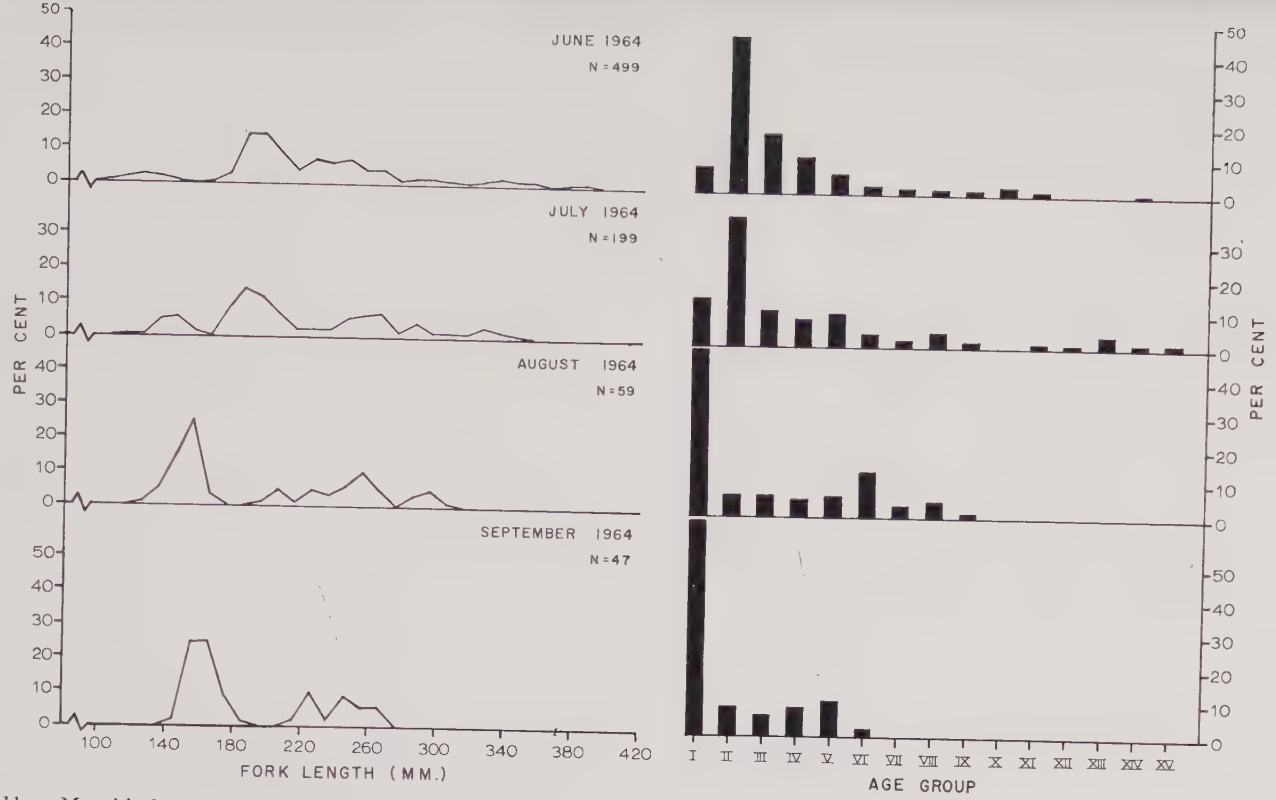

Figure 11. Monthly length- and age-frequency distributions (number of specimens each month the same for both) of scup caught by otter trawl during 1964.

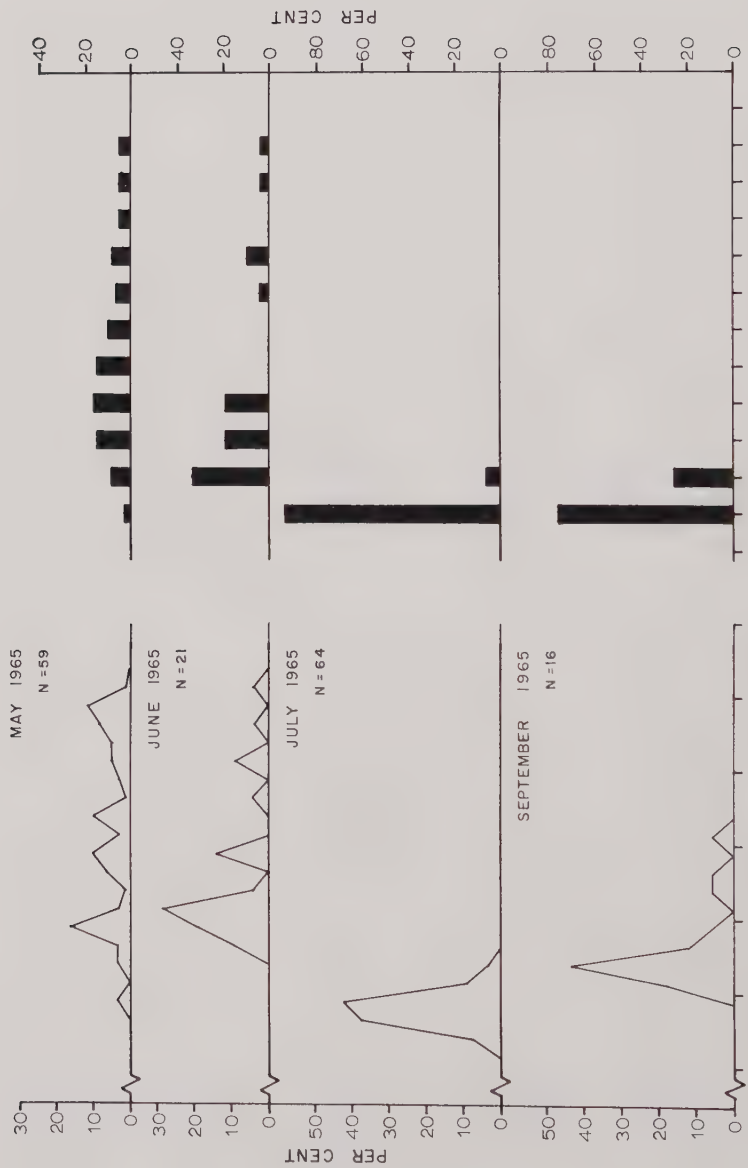

Figure 12. Monthly length- and age-frequency distributions (number of specimens each month the same for both) of scup caught by otter trawl during 1965.

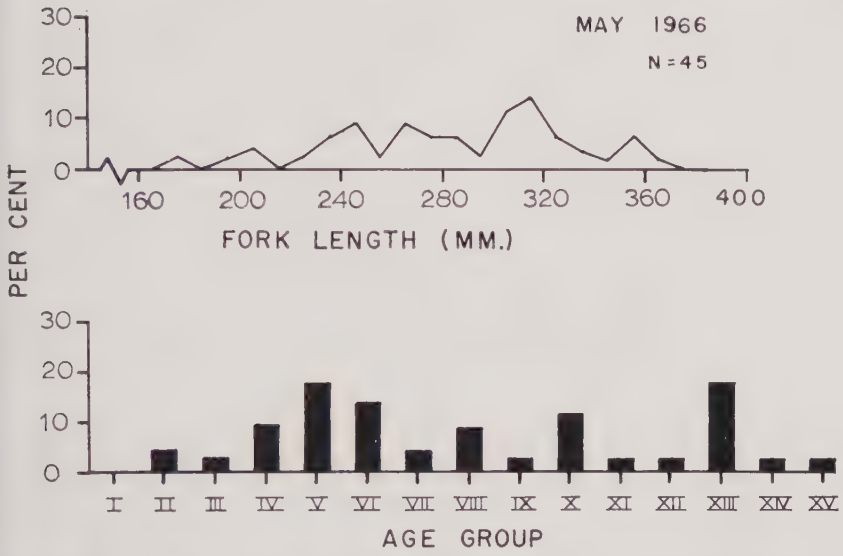

Figure 13. Length- and age-frequency distributions (number of specimens the same for both) of scup caught by otter trawl during May of 1966.

Otter Trawl With a Small-mesh Liner

Monthly size and age distributions of scup collected in 1964 by an otter trawl with a small-mesh liner are shown in Figure 14. One-year-old scup of the 1963 year class dominated the catch, between 75 and 100 per cent of each month's collections being representatives of this age group.

The 1963 year class appeared in large numbers in August of 1965 and again dominated the monthly catch (which included fish as old as 13 years). However, the age composition had changed considerably by September when fish older than age IV were absent and young of the year constituted over 70 per cent of the catch (Figure 15).

Too few scup (N = 10) were collected by this type of gear during July of 1966 to warrant making any reliable estimates of the size and age composition. By August of 1966, young-of-the-year fish accounted for over 80 per cent of the catch, a situation which was repeated in the following month (Figure 16).

DISCUSSION

Scup first appear along the south shore of Long Island where they are caught in ocean pond nets during April. They subsequently arrive in the Peconic Bays a few weeks later, usually by early May, and remain in these waters until October when they migrate eastward to

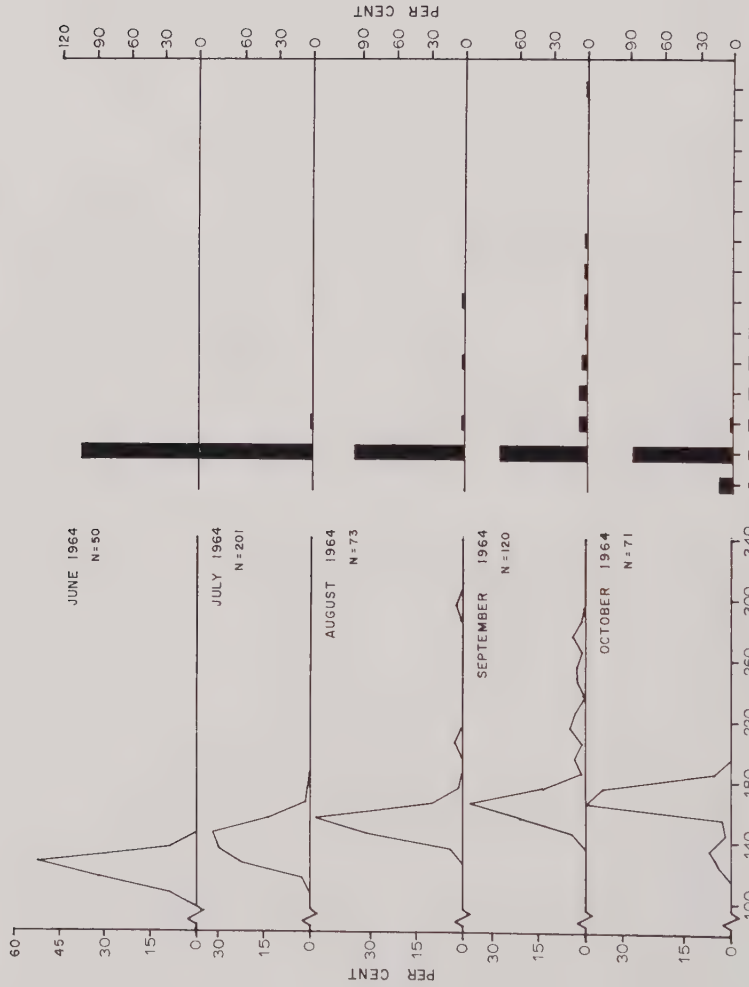

Figure 14. Monthly length- and age-freqency distributions (number of specimens each month the same for both) of scup caught by otter trawl with small-mesh liner during 1964.

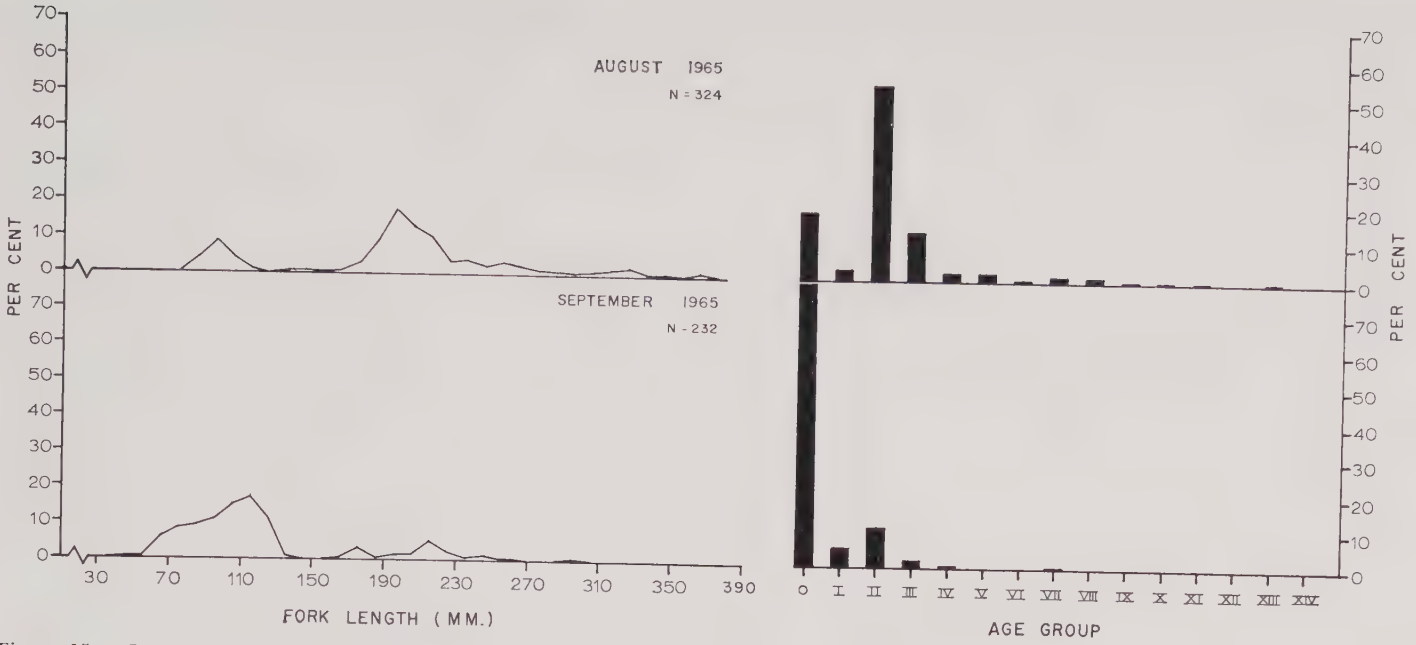

Figure 15. Length- and age-frequency distributions (number of specimens each month the same for both) of scup caught by otter trawl with small-mesh liner during August and September of 1965.

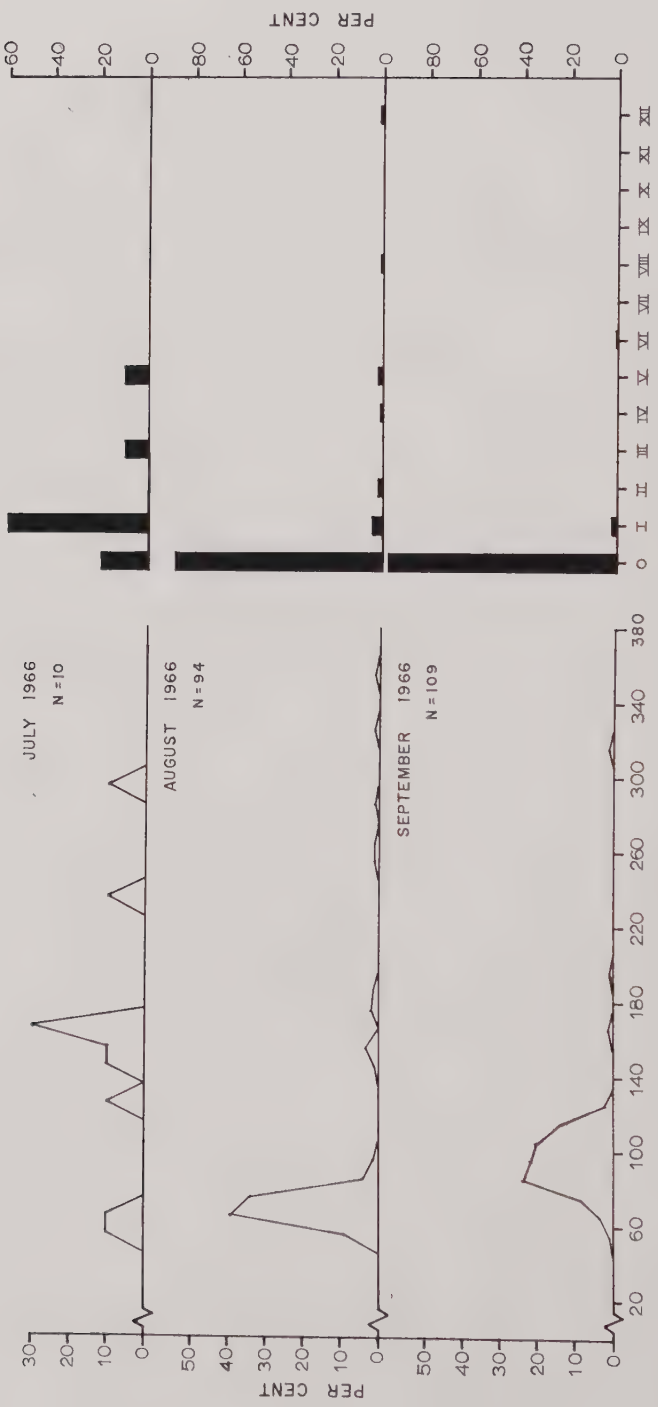

Figure 16. Monthly length- and age-frequency distributions (number of specimens each month the same for both) of scup caught by otter trawl with small-mesh liner during 1966.

the Atlantic Ocean off Montauk Point and, subsequently, to the south (Finkelstein, unpublished data).

During the present study the first specimens were taken on May 2 in 1964, May 7 in 1965 and May 11 in 1966; the last specimens were collected on October 8 in 1964, October 8 in 1965 and September 29 in 1966. Bottom temperatures and salinities ranged from 52° to 55° F. and 29.0 to 29.4 0/00, respectively, on the spring dates, and from 56° to 61° F. and 30.4 to 32.4 0/00, respectively, on the fall dates.

The arrival pattern of scup relative to fish size has been previously described by several authors. Bean (1903), for example, stated that, "The scup comes into our northern waters in great schools, the large spawning fish coming first, making their appearance in New York waters in May." Bigelow and Schroeder (1953) also reported that, ". . . the first fish to arrive in spring are the large adults, with the immature fish following later," and Goode (1884) quoting Professor Baird, remarked, "It makes its appearance, at least in considerable quantity, on the coast of New England about the middle of May, although the advance-guard of very large fish arrive sometimes as early as the middle of April; and it is most abundant toward the 1st of June, and arrives in successive detachments or 'runs' differing in size, the smallest fish coming last." While the above pattern was not specifically paralleled by the data of the present study, it was observed that the greatest quantities of large scup were collected early in the season, primarily during the month of May (Figures 12 and 13).

The spawning period of scup has been well established. According to Bigelow and Schroeder (1953), "Along southern New England scup spawn from May to August, but chiefly in June. Probably spawning both commences later and continues later for the few fish that manage to summer in Massachusetts Bay, and it may be assumed that they spawn wherever they summer." Nichols and Breder (1926) mentioned that scup spawn during June at Woods Hole in Massachusetts and that males with running milt are found in Sandy Hook Bay (New Jersey) from June 1 to June 23. Perlmutter (1939) further observed that scup spawned in Long Island waters from May to August, with the height of spawning in June. Wheatland (1956) studied egg collections from Long Island Sound and found indications that the spawning period extended from the end of May to the end of July in 1952, and from the beginning of June to the first week of July in 1953. Based on observations made during this study, i.e., the condition of the gonads of adult scup in spring and summer, the first appearance of young fish during the late summer and the size distribution of these small fish, it appears that scup began to spawn in the

Peconic Bays as soon as they arrived in May and continued to spawn through the month of June and in some instances into July.

The growth rate of scup has been reported by various authors. Nichols and Breder (1926) reported that, "At a temperature of 72°F. the eggs hatch about 40 hours after extrusion. On hatching, the larvae measure about 2.8 millimeters." Goode (1884), in quoting Professor Baird, mentioned that scup grow rapidly and are 2½ to 3¼ inches long by October and that, when they reappear the next season, they measure about 6 inches and by September average 8 inches. A year later they are 10 inches long, while the following year they average 12 inches and in their fifth year they measure 14 to 15 inches. Nichol and Breder (1926), on the other hand, presented data which seem highly inconsistent and conservative in relation to those presented by Goode (1884). These authors made measurements and examined scales of scup from Sandy Hook (New Jersey) and indicated the growth rate in average standard length as follows: 70 millimeters (2.8 inches) in the first winter, 112 millimeters (4.4 inches) in the second winter, 117 millimeters (4.6 inches) in the third winter and 180 millimeters (7.1 inches) in the fourth winter.

Moreover, Neville and Talbot (1964) stated that scup spawned in May and June, and quoted the following average modal lengths at the end of the summer season (September-October) for the first five years of age: age 0, 90 millimeters; age I, 165 millimeters; age II, 205 millimeters; age III, 225 millimeters; and age IV, 245 millimeters. Bigelow and Schroeder (1953) reported that, "In southern New England waters fry of 2 to 3 inches, evidently the product of that season's spawning, have been taken in abundance as early as September; they are 2½ to 3¼ inches long in October, and they may be as long as 4 inches at Woods Hole in November. Apparently young scup grow very little during the winter, for many of 4 inches are seen in the spring, probably the crop of the preceding season."

In the present study it was found that, at the time of annulus formation, the average sizes of scup (sexes combined) at successive ages were as follows: age I, 106.5 millimeters; age II, 161.2 millimeters; age III, 204 millimeters; age IV, 237.3 millimeters; age V, 263.5 millimeters; age VI, 284 millimeters; age VII, 299.9 milimeters; age VIII, 312.5 millimeters; age IX, 322.5 millimeters; and age X, 330.7 millimeters. Furthermore, as reflected by scale growth (Figures 2, 4 and 5), scup apparently gain most of their annual size increment while in inshore waters, i.e., between June and November. There is seemingly little growth accrued during winter.

It is interesting to observe differences between the selectivity of the types of gear which were employed during the present study. In

June and July of 1964, for example, age II was the dominant group of scup caught by otter trawl (Figure 11). However, during the same time period and while fishing in the same locations, the catch of the otter trawl with a small-mesh liner was limited almost entirely to small fish of age I (Figure 14). This suggests that while 1-year-old scup were apparently present in large numbers at the sampling stations, they were not captured in the otter trawl because of escapement through the large mesh.

The haul seine was effective in collecting primarily young-of-the-year scup. Although 407 young of the year were taken in three years of haul seining, only one 1-year-old scup was collected (Figure 10). Undoubtedly, the reason for the preponderance of young of the year in the haul-seine catches was that this age group occurs in abundance in the immediate shore zone, where seining was conducted, while older, larger fish do not normally inhabit this environment.

In addition to length and age differences observed between catches made by several types of gear during the same year, it was also evident that similar differences occurred between catches made by the same gear in successive years. For example, young-of-the-year scup collected by haul seining in 1966 were smaller than those taken in 1965 (Figure 10). A possible explanation for this size difference is that adult scup appeared in the Peconic Bays more than 2 weeks later than usual in the spring of 1966. Consequently, spawning probably occurred at a later date, and, thus, fish collected in 1966 would not have had as long a growing season as that in 1965.

Although hook-and-line fishing was limited to June of 1965 and 1966, differences were observed between the age composition of the catches made in each year. In June of 1965, age groups II and III were dominant, while in June of 1966 ages III and IV were dominant (Figure 8). The size differences observed between years for these catches suggest that the 1962 and 1963 year classes were evidently rather successful. Further indication of this is reflected by the otter trawl catches (Figures 11 and 12).

In contrast, the 1964 year class apparently was unsuccessful since haul seining in 1964 yielded no young-of-the-year fish at all. In 1965, there were no age I fish caught by otter trawl (Figure 12), only a very small number were taken by otter trawl with a liner (Figure 15) and none was captured by hook and line (Figure 8). Tracing this year class into 1966, it was observed that only a small number of age II fish were caught by otter trawl in May of that year (Figure 13), a negligible number were collected by otter trawl with the small mesh liner (Figure 16) and only a few were taken on hook and line

(Figure 8). Briggs (1968) also reported that a size group of scup was absent from his catch data, suggesting the failure of a year class whose origin was prior to 1965. It appears that this missing size group was the 1964 year class.

During the 3-year period in which scup were studied in the Peconic Bays, there appeared to be more juveniles present in 1966 than in the two previous years combined. Indeed, in May of 1966, running ripe females were collected for the first time. In August and September, catches of small fish made by haul seine and by otter trawl with a liner were so large that only small samples were retained for age and growth analysis, while hundreds of young scup were returned to the water.

In addition to the observed differences already noted between catches according to method and year of capture, differences were observed between catches made early and late in the season. For example, the large, old fish which were collected in large numbers in May were no longer observed in quantity in the catches during the summer and fall. The large scup most probably move eastward into Gardiners Bay and the Montauk Point area with the advance of summer (Finkelstein, unpublished data).

CONCLUSIONS

The scup from historical times to the present has exhibited extreme fluctuations, from periods of great abundance to periods of such scarcity that the species was virtualy absent from our coast for years (Bean, 1901; Neville and Talbot, 1964). Based on observations during the present investigation, the fluctuations apparently are the result of the relative success or failure of annual brood production. Furthermore, it would appear that the number of young which are produced may not necessarily be dependent upon the size of the spawning stock. Neville and Talbot (1964) reported that a recovery to a record high level of abundance in 1929 followed a period of unusually low yield (1926-1928) when adult scup were not very numerous. Therefore, it would seem that, as an influence on population abundance, restrictions on either the sport or commercial fisheries would have little measurable effect.

Nevertheless, while this appears to be a valid conclusion from the available data, unrestricted fishing may not be the wisest use of the resource with regard to the maximum sustained yield of the fishery. The formulation of any restrictions to control yield, however, cannot be logically derived from age and growth information alone. Mortality data, at least, are also required.

At present, scup less than 7 inches in total length may not be legally bought or sold in New York. This size limit permits scup to

be marketed at 1 and 2 years of age, and these fish are for the most part immature. Because the species grows very rapidly in terms of length and weight during its first five years of life and is capable of living to at least 15 years of age, the merits of this size limit are doubtful. Meaningful evaluation of this restriction would require additional biological information.

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EFFECT OF TYPE OF ROAD ON SUMMER ROADSIDE COUNTS OF COTTONTAILS[1]

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ABSTRACT

Roads on two rabbit survey routes in Albany County were classed as secondary or main according to their designation on U. S. Geological Survey maps. Standardized early-morning counts of rabbits for 11 years on one route and nine years on the other were grouped according to the type of road with which they were associated. Statistical analysis, applied to several aspects of the data, indicated that the pattern of variation in peak and total annual counts on the two types of road differed significantly on both routes.

Summer roadside counts of cottontail rabbits have been made in New York for several years as a means of recognizing trends in the abundance of this species over the State. Survey routes have been established throughout the cottontail range, and the work consists of counting all rabbits seen from a slow-moing vehicle during early-morning hours on several days within a standard period in mid-July. Certain weather data and other information are also recorded, and studies have indicated criteria for several of these that may be used to obtain comparable counts for different times and places (Alkon, 1965). For example, counts made wholly or partially in winds of 8 m.p.h. or higher, in rain or in heavy fog are discarded. Also, counts on the same route are considered comparable only if the starting time of the surveys did not vary by more than 15 minutes. Another factor that may influence the comparability of counts is the type of road on which they were made. In this respect, however, there has been no specified composition of the routes used, except that they be comprised of secondary rural roads insofar as possible. Major two-lane thoroughfares are often included, if only as links between available secondary roads.

There are several reasons for believing that the type of road affects the number of rabbits seen. The standard survey procedure

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is for a route to be traversed at a speed of 15 to 20 m.p.h., and observers are instructed to stop for 3 minutes after encountering another moving vehicle. This can be done consistently on secondary roads but, because of traffic interference, is not always practicable on main roads. Also, traffic and other human activities may affect the behavior of rabbits so as to lessen their observability to a greater degree on main roads than on secondary roads.

Therefore, a study of past records was undertaken as a pilot investigation to determine whether counts on secondary and main roads differed with respect to rates of observation, daily variation and annual variation. The chief objective was to determine whether counts from the two types of road may be combined or whether, in a statistical sense, they represent different populations. Since the primary purpose of these surveys is to estimate yearly fluctuations in rabbit abundance, findings relating to annual variation in counts are especially important.

METHODS

Records for the Unionville and Meadowdale routes in Albany County were used. They are approximately 21 and 28 miles long, respectively, and tranverse a mixed hardwood, farmland and sparse urban environment. The Meadowdale route includes one village. The roads making up these routes were classified as secondary or main according to their designation on 7½° U.S. Geological Survey topographic maps[3] as follows:

secondary — those designated as "light duty" or "unimproved roads"

main — those designated as "heavy duty" or "medium duty" roads

These designations, as used by the U. S. Geological Survey, are based on the quality and capacity of the road construction rather than on traffic volume or roadside cultural development. Heavy duty roads are well surfaced and maintained, built on a heavy foundation and capable of carrying unrestricted loads at all seasons. Light duty roads, on the other hand, are loose surfaced (including oiled gravel and water-bound macadam) and regularly maintained, but suitable only for light traffic. Previously, the roads had been classed as secondary or main on the basis of subjective appraisals of traffic volume and roadside cultural deelopment as well as construction. Comparison showed close agreement with the classification derived from the topographic

[3] The quadrangles involved were: Altamont (1944), Clarksville (1953) and Voorheesville (1954).

TABLE 1. COMPOSITION OF UNIONVILLE AND MEADOWDALE ROUTES BY TYPE OF ROAD

Type of road	Total miles	Percentage of route	Number of sections	Miles per section
Unionville				
Secondary	17.0	81.0	4	4.3
Main	4.0	19.0	4	1.0
Total	21.0	100.0	8	2.6
Meadowdale				
Secondary	16.9	60.4	7	2.4
Main	11.1	39.6	6	1.9
Total	28.0	100.0	13	2.2

maps. On each route contiguous roads of the same type were designated as a section. The junctions of secondary and main roads thus became section boundaries. The composition of the two routes is shown in Table 1.

Because the study dealt with past observations of cottontails which had not been mapped, it was necessary to ascribe them to the proper road sections on the basis of the mileage records kept. The original observations had been recorded to the nearest 1/10 mile, but because of variations in the speedometers of the different cars employed, absolute mileage records could not be used directly. However, in each case the total mileage had been recorded as registered on the particular speedometer involved. Therefore, each route was traversed to determine in terms of one speedometer its total length and the distance from the starting point to each section boundary, and the percentage represented by each section was computed. Then, by applying these proportions to the total mileage recorded for each previous run, the distance to each section boundary in terms of the absolute mileage for that run was calculated. This made it possible to assign each observation to the proper road section.

There is no assurance that errors in location were not made. The inherent precision of observations (i.e., to the nearest 1/10 mile) was fairly gross. For example, a rabbit recorded at a mileage of 5.7 could actually have been anywhere between 5.65 and 5.75 miles, a distance of over 500 feet. But this potential error would be important only for rabbits seen near section boundaires, and it was assumed that such errors would tend to be compensatory. Occasionally, observers noted with the mileages the roads which they were traversing; in these cases, the "calculated" section was the same as that recorded by the observer.

Records for 11 years (1954-1964) on the Unionville route and for nine years (1955-1964, except 1961 when mileage notations were in-

adequate) on the Meadowdale route were used. The data for each route were treated separately, and only combined counts (adults, juveniles and undetermined animals) for each road type were considered.

Comparisons were made by chi-square or M-square, and statistical interpretations were based on the assumption that there was no difference in the data for the two road types. Thus significant chi-square or M-square values would indicate that a real difference did exist.

FINDINGS

After being grouped according to type of road, the data were compared with respect to rate of observation and daily and seasonal variations.

Rate of Observation

Rates of observation were compared in terms of rabbits seen per mile (Table 2). On the Unionville route, this rate was consistently higher on secondary roads than on main roads, the difference being highly significant in 10 of the 11 years. On the Meadowdale route, the

Table 2. Comparative Rates of Observation on Secondary and Main Roads on Unionville and Meadowdale Routes

Year§	Rabbits seen per mile		Chi-square†
	Secondary roads	Main roads	
Unionville			
1954	3.57	0.83	18.26**
1955	4.69	0.73	30.01**
1956	1.85	0.35	15.90**
1957	1.28	0.51	3.43
1958	1.55	0.41	10.57**
1959	2.07	0.51	46.88**
1960	2.37	0.55	49.04**
1961	1.65	0.06	25.06**
1962	2.01	0.40	23.14**
1963	1.83	0.10	28.42**
1964	1.90	0.34	17.37**
Meadowdale			
1955	1.98	1.70	0.41
1956	0.50	0.45	0.01
1957	1.15	1.41	0.82
1958	0.98	1.05	0.08
1959	0.75	1.11	7.46**
1960	1.55	0.82	19.04**
1962	1.06	1.61	1.15
1963	0.93	1.18	0.62
1964	1.46	0.47	17.84**

** Significant at 1 per cent level.
§ Data for 1961 on Meadowdale route omitted because not comparable.
† Actual counts, rather than number seen per mile, used in calculating chi-square values.

rates were more nearly even, the difference being significant in only three of the nine years.

DAILY VARIATION

Data for each year were tested by chi-square analysis. However, it was considered prerequisite that the "expected" component of the formula be five or more, and on the Unionville route counts on the main roads were too low for analysis. Therefore, tests were restricted to useable counts from the Meadowdale route. In no year did the relative daily distribution of counts differ significantly according to road type (Table 3).

TABLE 3. DAILY VARIATION IN COUNTS ON SECONDARY AND MAIN ROADS ON MEADOWDALE ROUTE

Year	Type of road	Number of rabbits counted each day									Chi-square*
		1	2	3	4	5	6	7	8	9	
1955	Secondary	36	32	..	..	..	..	..	..	..	0.07
	Main	23	17	..	..	..	..	..	..	..	
1956	Secondary	7	10	..	..	..	..	..	..	..	1.27
	Main	2	8	..	..	..	..	..	..	..	
1957	Secondary	16	24	16	..	..	..	..	..	..	3.79
	Main	11	28	7	..	..	..	..	..	..	
1958	Secondary	21	10	11	24	15	..	..	..	..	0.93
	Main	13	9	10	16	9	..	..	..	..	
1959	Secondary	14	10	8	17	15	10	11	14	11	12.10
	Main	6	10	15	17	13	20	13	8	6	
1960	Secondary	12	15	45	37	25	22	29	..	..	4.21
	Main	5	6	15	9	6	13	11	..	..	
1963	Secondary	16	16	..	..	..	..	..	..	..	1.01
	Main	10	17	..	..	..	..	..	..	..	
1964	Secondary	14	22	39	..	..	..	..	..	..	1.33
	Main	2	7	7	..	..	..	..	..	..	

* None of these values was significant at the 5 per cent level.

ANNUAL VARIATION

Two types of data were tested, i.e., peak annual counts and total annual counts. A peak count represents the highest number of rabbits seen on one coverage of a route in a given year. The occurrence of such peaks reflects fluctuations in daily counts, and routes are covered several times each year in an effort to obtain a representative peak

Table 4. Annual Variation in Peak Counts on Secondary and Main Roads on Unionville and Meadowdale Routes

Year	Number of rabbits counted		Sum of M-square chi-square§
	Secondary roads	Main roads	
Unionville			
1954	83	6	
1955	98	5	
1956	41	3	33.31**
1957	35	4	
1958	37	2	
1959	58	3	
1960	65	0	analysis
1961	34	1	not made
1962	41	2	(see text)
1963	39	1	
1964	55	3	
Meadowdale			
1955	36	23	
1956	10	8	
1957	24	28	
1958	24	16	
1959	17	20	28.09**
1960	45	15	
1962	18	18	
1963	16	17	
1964	39	7	

** Significant at 1 per cent level.
§ M-square used for Unionville data; chi-square for Meadowdale data.

count. A chi-square analysis could be used for counts from the Meadowdale route, but again the values for the Unionville route were too low. For the latter route, because of the special pertinence of annual comparisons, an M-square analysis (Steel and Torrie, 1960) was applied. The statistic "M-square" has a distribution similar to that of chi-square with two degrees of freedom, and the total M-square is based on the sum of deviations from the expected ratio for each year.

The data used and the results of the analyses of peak counts are shown in Table 4. On both routes the pattern of variation on secondary roads were significantly different from that on main roads. For the Unionville route, the cumulative M-square value for only the first five years was larger than that required to show a significant difference for all 11 years; therefore the remaining years were omitted from the analysis.

In comparing total annual counts, analysis was arbitrarily limited to data for years in which a route was covered at least three times. Accordingly, data for seven years could be used for the Unionville route, while those for only three years could be used for the Meadowdale route. With respect to the latter, however, variations in starting

TABLE 5. ANNUAL VARIATION IN TOTAL COUNTS ON SECONDARY AND MAIN ROADS ON UNIONVILLE AND MEADOWDALE ROUTES

Year	Number of rabbits counted		Sum of chi-square
	Secondary roads	Main roads	
Unionville			
1956	117	5	
1958	72	7	
1959	198	14	
1960	191	5	15.32*
1961	95	0	
1963	123	2	
1964	165	8	
Meadowdale (set 1)			
1958	71	48	
1959	52	58	11.61**
1960	62	25	
Meadowdale (set 2)			
1958	71	48	
1959	53	44	6.22*
1960	74	30	
Meadowdale (set 3)			
1958	56	39	
1959	53	42	7.29*
1960	103	41	

* Significant at 5 per cent level.
** Significant at 1 per cent level.

time resulted in three sets of counts that were comparable, i.e., representing runs that began within 15 minutes of each other. A chi-square analysis was used for the data from both routes. Here again, the results (Table 5) indicate that the pattern of variation on secondary roads was significantly different from that on main roads.

DISCUSSION

On the Unionville route consistently more rabbits were seen per mile on secondary roads than on main roads, while on the Meadowdale route the rates of observation were similar on the two types of road in most years. Daily variation in counts, analyzed only for the Meadowdale route, was similar in all years. But, on both routes, the pattern of variation in peak and total annual counts on the two types of road differed significantly.

These findings may be considered from two different but not unrelated points of view. First, with respect to their applicability to a roadside survey method, the implications are relatively clear. As a means of measuring trends in rabbit abundance from year to year, annual counts from secondary roads cannot be combined directly with

those from main roads. This information will be useful in connection with analyzing data from other cottontail survey routes in the State. It also should lead to improved standards for the composition of survey routes and may indicate that certain routes or parts thereof that comprise main roads should be discontinued.

Second, their relevance to knowledge of the behavior of cottontails is much less clear. This is of more than academic interest because correlation of survey techniques with characteristics of rabbit behavior is necessary for a realistic interpretation of data. For example, on the Meadowdale route variation in the annual counts would suggest that the rabbit populations associated with the two types of road were different. Yet this was not true with respect to daily counts. Perhaps a difference in behavior was involved, but without more basic knowledge of the animal this cannot be considered a valid deduction.

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SEASONAL OCCURENCE OF MACROINVERTEBRATES IN A GREEN-TREE RESERVOIR[1]

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ABSTRACT

The Montezuma National Wildlife Refuge in central New York provides a green-tree reservior during the spring. The impoundment is important for waterfowl nesting and is potentially valuable as a waterfowl feeding area. Periodic samples of invertebrate organisms were collected during April, May and June in 1966, and 27 different kinds were encountered; some species occurred in very large numbers. Although a few animals were numerous soon after the ice disappeared, the number of species and the biomass generally increased as the season progressed. It is concluded that a potentially important source of duck food, in the form of aquatic invertebrates, is available during these three months.

In recent years wildlife biologists and foresters have been attempting to evaluate the ecological effects of flooding on wooded lowlands. Several authors (Yeager, 1949; Cowardin, 1965; Munro, 1965) have documented the effects of permanent flooding on this kind of habitat. Others (McDermott and Minckler, 1961) have appraised the effects of fall flooding in the development of public duck hunting areas. Their work indicates that timber management objectives and game management objectives are entirely compatible. Total acorn production was somewhat greater on flooded areas as compared with normal (unflooded) areas. This is significant because the abundance of many dabbling ducks, primarily mallard (*Anas platyrhynchos*) and wood duck (*Aix sponsa*), is strongly correlated with acorn abundance, especially when the mast has been covered with water. However, although some research has been undertaken, few investigators have assessed the role of flooded green-timber impoundments in relation to waterfowl nesting and food availability during the spring. Reed (1966) has shown that nest density in these green-tree reservoirs is sometimes high (one nest per 4 acres). The present paper documents the relative abundance and taxonomic diversity of the

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potentially important invertebrate animals which exist in an impounded area in central New York.

THE STUDY AREA

The Montezuma National Wildlife Refuge is a 6,300-acre tract at the northern end of Cayuga Lake in Seneca County. The southern portion of the Refuge (600 acres) has been managed since 1964 as a green-timber impoundment for both nesting and migrating waterfowl. During April, May and June in 1966, half (300 acres) of this area was inundated to an average depth of 12 inches. After this depth was reached, it was maintained by drawing water from a nearby canal with a diesel pump having a capacity of 6,000 gallons per minute.

The area is characterized as a mature stand of bottomland hardwoods with a closed canopy. The principal tree species included red maple (*Acer rubrum*), American elm (*Ulmus americana*), red ash (*Fraxinus pennsylvanica*) and swamp white oak (*Quercus bicolor*). The growth of shrubs and herbaceous ground cover was moderately rich in both species and abundance. Common shrubs included deciduous holly (*Ilex verticillata*), highbush blueberry (*Vaccinium corymbosum*), ironwood (*Carpinus caroliniana*), poison ivy (*Rhus toxicodenron*), and spice bush (*Lindera benzoin*). Herbaceous plants included arrow arum (*Peltandra virginica*), false nettle (*Boehmeria cylindraca*), spotted touch-me-not (*Impatiens capensis*) and several species of ferns (Filicineae). The soils are Carlisle muck (Pearson *et al.*, 1942), the surface foot being a nearly black, well-decomposed, organic muck which overlays a grayish marl-like material.

Although the area is basically flat, undulations in the form of small hummocks and shallow depressions are common. Consequently, a few pools of water remain throughout the year, even though the site is drained in late June and early July each year.

Large numbers (thousands) of waterfowl made use of the flooded green-timber impoundment during spring migration, and nest density was high compared with that for other areas on the Refuge and in surrounding habitats. Therefore, it was appropriate to obtain information on the relative abundance and taxonomic diversity of invertebrate organisms living there. These protein-rich animals are of interest primarily because they may be providing an essential source of food to such groups of ducks as egg-laying females, ducklings and molting adults (Holm and Scott, 1954; Hawkins, 1964; Leitch, 1964).

MATERIALS AND METHODS

A wire household strainer 8-inches in diameter (U.S. Standard Sieve Series No. 16) was employed to obtain invertebrate collections

six times each month. The strainer was swept rapidly through the water and along the substrate at approximately 50 randomly selected locations throughout the study area. Organisms caught in the strainer were placed in glass vials containing 70 per cent ethyl alcohol and taken to the laboratory for identification and determinations of relative abundance and comparative biomass. Only macroinvertebrates (plus one vertebrate species) were recorded.

RESULTS

The organisms identified during successive half-month periods are listed according to their relative abundance in Table 1. It is apparent that the variety of species generally increased from early April to late June. Not evidenced by these data is the fact that the total available biomass showed a similar increment. Therefore, although there was a considerable abundance of animal life soon after the ice melted in early April, both the diversity of organisms and the biomass increased continually until the area was drained in late June. Thus, a potentially important source of duck food was available during spring migration and most of the nesting season.

Fairy shrimp (*Chirocephalopsis bundyi*) were first recorded April 4, and by April 22 the population had disappeared. During much of this period visual observations indicated that nearly every square meter of water contained "thousands" of individuals. Kenk (1949) stated that sudden declines in these organisms are associated with an increase in predatory insects. No predatory insects were observed in the study area, however, until well after the fairy shrimp population had disappeared. Pennak (1953) related that the appearance and sudden disappearance of fairy shrimp is governed largely by water temperature. Because these animals are primarily inhabitants of shallow, vernal waters which dry up during the summer, new populations are produced each spring when the area is again covered with several inches of water. This is simply a characteristic feature of this animal group.

Mosquito larvae (*Aedes* sp.) represented the second most numerous organism during April. Visual observations indicated that "hundreds" of individuals occupied nearly every square meter of water. By mid-May, however, they were no longer observed. Of the common mosquitos encountered in central New York, this genus is the only one typically associated with temporary bodies of water. Its eggs are deposited during the fall in areas which are destined to be inundated during the winter and spring, and the larvae become evident soon after the ice thaws.

Table 1. Organisms Identified, According to Half-month Periods, in Samples from Green-timber Impoundment on Montezuma National Wildlife Refuge in 1966*

April		May		June	
First half	Second half	First half	Second half	First half	Second half
Chirocephalopsis bundyi	*Chirocephalopsis bundyi*	*Lymnaea* sp.	*Lymnaea* sp.	*Lymnaea* sp.	*Lymnaea* sp.
Aedes sp.	*Aedes* sp.	*Gammarus fasiatus*	*Gammarus fasiatus*	*Gammarus fasiatus*	*Gammarus fasiatus*
	Lymnaea sp.	*Aedes* sp.	*Musculium* sp.	*Sphaerium* sp.	*Sphaerium* sp.
	Gammarus fasiatus	*Asellus militaris*	*Sphaerium* sp.	*Asellus militaris*	*Asellus militaris*
	Aplexa hypnorum	*Sphaerium* sp.	*Asellus militaris*	Tendipedidae	*Dytiscus* sp.
	Asellus militaris	*Aplexa hypnorum*	*Aplexa hypnorum*	Leptoceridae	*Callicorixa* sp.
	Tendipedidae	*Dytiscus* sp.	*Dytiscus* sp.	*Acilius* sp.	*Hesperocorixa* sp.
	Phagocata sp.		*Ambystoma maculatum*	*Aeschna* sp.	*Sigara* sp.
				Aplexa hypnorum	*Musculium* sp.
				Helisoma sp.	Leptoceridae
				Lestes sp.	*Buenoa* sp.
				Benacus griseus	*Notonecta* sp.
					Gyraulus sp.
					Aplexa hypnorum
					Helisoma sp.
					Gerris sp.
					Berosis sp.
					Eylais sp.

* For each period, organisms are listed in descending order of relative abundance.

Pulmonate snails (*Lymnaea* sp.) were the most abundant invertebrate throughout May and June. Sample counts indicated that an average of 70 (±35) of these large snails existed on nearly every square meter of substrate. This genus can withstand dry periods by burrowing into the mud and aestivating; thus, it can maintain large populations from year to year.

Other organisms collected, i.e., the aquatic sowbug, *Asellus militaris*, and the fingernail clams, *Musculium* sp. and *Sphaerium* sp., also burrow into the substrate and aestivate during adverse environmental conditions. Still others, i.e., the amphipod, *Gammarus fasiatus*, and the insect representatives, have no outstanding ability to withstand severe changes in the environment. These latter animals, or their eggs or cysts, must have come into the timbered area by one of several means. Spring floodwaters, water pumped into the area from the nearby canal, insect immigration and vertebrate visitants (primarily birds) were all distinct possibilities. Also, the few pools of water which remain throughout the year provide small reservoirs of animal organisms that may repopulate the entire area when it is inundated in early spring. Finally, spring flooding stimulates natural population development of many of the invertebrate species which are in various forms of encystment prior to flooding.

Although the early spring populations of fairy shrimp and mosquitos were by far the largest, the total biomass of all animals still increased as the season progressed. This occurred because more kinds of animals were being encountered, their average size, and consequently weight, was much greater than that of either the shrimp or mosquito, and the common organisms became more abundant during the 3-month sampling period. Particularly evident in June was the pronounced increase in larval and adult insects.

These data indicate broadly the abundance and diversity of animal organisms in flooded green-tree reservoirs in central New York. More thorough evaluation would be desirable, particularly if it can be demonstrated that these protein-rich invertebrates play a necessary role in the welfare of waterfowl populations.

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GENERAL NOTES

OXYGEN REQUIREMENTS OF THE WALLEYE

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Although considerable literature refers to the walleye (*Stizostedion vitreum*), there seem to be little published data on its oxygen requirements. However, Hewson (1959) reported that amounts of dissolved oxygen and free carbon dioxide appeared unrelated to the catch of walleyes in Lake Winnipeg where dissolved oxygen was in good supply, varying between 7 and 12 cubic centimeters per liter. Smith and Kramer (1965) recorded mortality in fingerling walleyes at an oxygen concentration of 4.5 ppm in water containing ground conifer fiber and noted increased mortality as the amount of fiber increased. An opportunity to obtain information concerning lethal oxygen concentrations arose while collecting adult shad (*Alosa sapidissima*) for oxygen studies.

Some 30 walleyes were captured with a 350-foot haul seine in the Delaware River a few miles below Hancock (N.Y.) on June 21, 1965. Eighteen fish that had

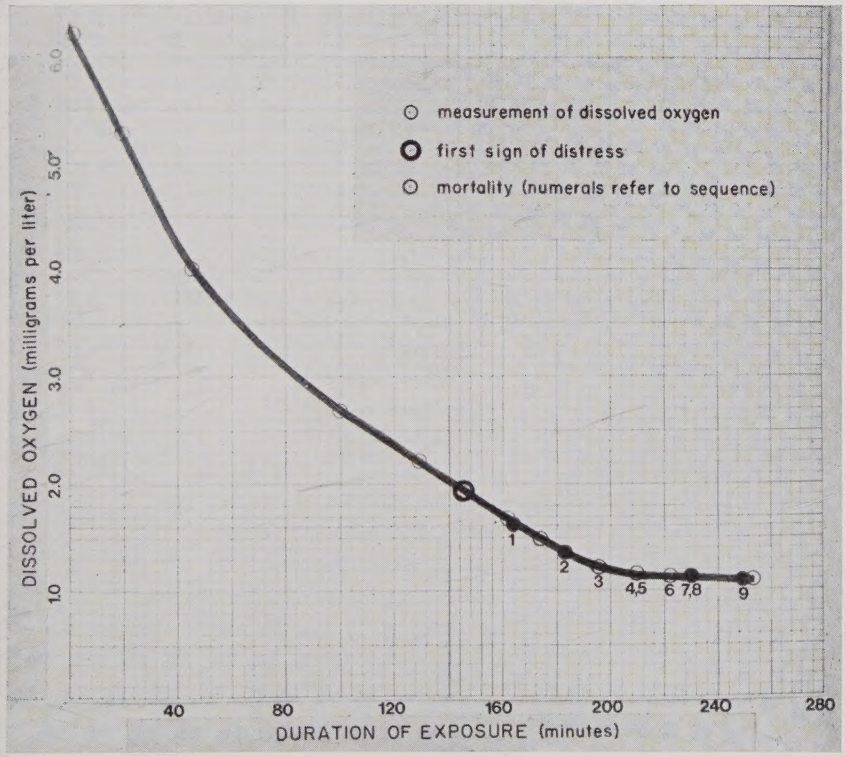

Figure 1. Curve showing response of walleyes to reduced levels of dissolved oxygen.

TABLE 1. LETHAL LEVELS OF OXYGEN FOR THE NINE WALLEYES THAT DIED DURING THE EXPERIMENT

Lethal oxygen level (in milligrams per liter)	Size of specimen	
	Total length (inches)	Weight (grams)
1.6	28.5	3,430
1.4	19.0	1,030
1.2	17.5	830
1.2	18.5	840
1.2	22.4	1,620
1.2	19.9	1,090
1.2	18.4	910
1.2	17.2	740
1.1	17.7	730

not been "gilled" were transported in washtubs to two 8-foot-diameter, circular, plastic wading pools located on the river bank. Fish were haphazardly assigned to the pools each of which contained some 500 gallons of river water.

Dissolved oxygen was removed by bubbling nitrogen gas through the water; earlier studies had shown that a pool was homogeneous in oxygen content during the process. A perforated plastic cover over the pool presumably reduced diffusion of oxygen into the water, yet it allowed nitrogen to pass out and shielded the walleyes from direct sunlight. Periodically, a water sample was taken, and its dissolved oxygen content was determined using the Alsterberg modification of the Winkler method. Cessation of respiratory movement was considered the criterion of death, and the dead fish was then removed from the pool and measured. The water temperature at the beginning of oxygen depletion was 75.2°F.

Figure 1 presents the observed behavior of the walleyes in response to decreasing oxygen concentration. Interpolated lethal levels and measurements of the corresponding fish are summarized in Table 1. Lethal oxygen values were within the range of 1.1 to 1.6 ppm, and all mortality occurred between 160 and 250 minutes after oxygen drawdown was begun.

It is to be emphasized that these values are not meant to be interpreted as values above which walleyes could be maintained for any considerable length of time. Also the authors are aware that inumerable factors would alter this lethal dissolved oxygen value. However, under the existing experimental conditions and rapid oxygen drawdown, these values represented lethal levels of dissolved oxygen for adult walleyes.

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UNUSUAL SITE FOR A WOOD DUCK NEST

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Records of exceptions to the habit of wood ducks (*Aix sponsa*) to nest in cavities are rare. Forbush (1916) noted reports of wood ducks nesting on the ground in the absence of suitable sites, but stated that he had never seen such a nest. Audubon is reported (Bent 1923) to have found a nest in the fissure of a rock. Grice and Rogers (1965) and Roberts (1936) mentioned no abnormal nesting by wood ducks in the presence of suitable cavities.

The author encountered a highly unusual wood duck nest on an experimental green-timber impoundment, of the type described by Thompson *et. al.* (1968), on the Montezuma National Wildlife Refuge. On several occasions during the early summer of 1966, a wood duck hen was flushed from atop a leaf and twig nest. With each successive observation of the duck flushing from this location, it became increasingly clear that she was using the site as a nest. This was later circumstantially confirmed by the finding of numerous wood duck shell fragments and the presence of a newborn duckling in the nest.

The nest was about 32 feet above the water in a swamp white oak (*Quercus bicolor*) about 18 inches in diameter and some 130 feet from the nearest timber edge. The nest structure was supported by small lateral branches and rested against the trunk of the oak. It was made of twigs and small sticks closely intertwined with oak leaves and measured about 20 inches in over-all diameter and about 8 inches from bottom to top. The nest cavity, approximately 8 by 8 inches and about 4 inches deep, was completely lined with wood duck down.

The impoundment was flooded to a depth of 8 to 10 inches, and there were numerous suitable nesting cavities in the surrounding timber (Reed, 1968). There seemed to be no pressure to force the duck into an open nest. Examination of the site in the summer of 1967 revealed no sign of further activity. Winter storms had damaged the nest beyond the point of usefulness.

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AN OCCURRENCE OF WIRE IN A WHITE-TAILED DEER'S LIVER

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A piece of wire was found lodged in the liver of a white-tailed deer killed by a hunter on The Archer and Anna Huntington Wildlife Forest Station during an experimental harvest in 1967. All female deer were brought intact to a checking station for removal of reproductive tracts, and each was routinely examined for gross abnormalities or internal parasites, including gross dissection of the liver to determine the incidence of liver flukes (*Fascioloides magna*). One liver, from a female estimated by the method of Severinghaus (1949) to be 4½ years old, had an essentially circular lesion approximately 20 millimeters in diameter near the

Deer liver and wire taken from it.

surface. The lesion appeared similar to those containing flukes in the livers of heavily infested deer. Upon dissection a piece of 19-gauge wire, 0.89 millimeter in diameter and 4.4 centimeters long, was discovered 3 to 5 millimeters beneath the surface. The deer appeared to have been in good health. Its live weigth of 152 pounds was typical of females of this age or older.

In the opinion of Dr. C. G. Rickard of the New York State Veterinary College at Cornell University it is likely that the wire was ingested, pierced the wall of the recticulum as that organ contracted, and lodged in the adjacent liver. Wire of this sort could have been picked up at any of over a hundred exclosures used to demonstrate effects of browsing activity. These areas were fenced with galvanized 2-inch-mesh chicken wire.

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